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THE JOURNAL OF ECONOMIC BIOLOGY.

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THE

JOURNAL OF ECONOMIC BIOLOGY.

CERATOTHRIPS BRITTENI, N. SP., A TYPE OF THYSANOPTERA NEW TO THE BRITISH FAUNA.

BY RICHARD S. BAGNALL, F.L.S.

(WITH 1 TEXT-FIGURE).

IN 1899 the late Prof. O. M. Reuter described *Ceratothrips trybomi* from Sweden[1] forming the type of a new genus characterised by the unusual antennal features, and upon the strength of which I recently separated it from the Thripidae s. s.[2] To some these may seem small characteristics upon which to place such value, but in the classification of an Order one must study the relative values of the chief characteristics. Thus characters of value in separating genera and families in one Order may be of little or no value in another. For instance, a character often used in other insect Orders, the relative distances between the coxae, in the Thysanoptera persists unchanged throughout the two suborders Terebrantia and Tubulifera, whilst the structure of the tarsi are also subject to but little variation.

Again, taking the antennae, we see that the same general 8-jointed type[3] persists throughout the Tubulifera. In the Terebrantia, after setting aside the Aeolothripidae and the Heterothripidae, each with distinctive antennal characters, we get the large group generally known as Thripidae, and we find that of the numerous genera and species known from all parts of the world the same general type of antennae is common, *i.e.*, composed of 6 larger or main joints and a single or double-jointed style, and having joints 3 and 4 at least furnished with

[1] Acta Soc. Pro Fauna et Flora Fennica, 1899, xvii (Addenda, p. 65).

[2] Ann. & Mag. Nat. Hist., 1912, pp. 220-222.

[3] The few species bearing 7-jointed antennae being undoubtedly derived from an 8-jointed form, a joint being lost by the fusion of the two apical joints.

single or double trichomes. It is true that some species possess a 6-jointed antennae (*e.g.*, *Aptinothrips rufa* and *Drepanothrips reuteri*), but in such cases the 6th joint is not styliform but pyriform, and caused, undoubtedly, by fusion with the style, as proved by the fact that *A. rufa* possesses a normal 8-jointed form as well as the 6-jointed form.

Therefore the very constancy of the general type of antenna gives a considerably higher taxonomical value to any deviation than would be otherwise the case, and such were the considerations that weighed with me when I proposed the family Ceratothripidae.

That (in the light of recent material) the classification of the Terebrantia requires considerable modification, cannot be gainsaid, and it seems to me that it should be divided into two main divisions, or tribes, the one Aeolothripides (for Aeolothripidae) and the other Thripides (for Heterothripidae, Thripidae (s.l.) and Ceratothripidae).

Tribe THRIPIDES.

Fam. **Ceratothripidae,** Bagn.

Genus **Ceratothrips,** Reut.

Easily recognised by the very distinctive type of antennae which have five main joints (six in the rest of the Thripide genera) and a single-jointed style. The third joint is pedicellate, very small and without trichome.

Ceratothrips britteni, n. sp.

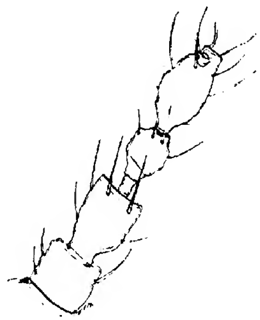
Length 1.3 mm., breadth of pterothorax 0.27 mm.

Colour dark grey-brown, head and thorax somewhat deeper in colour than the rest of the body. Apex of 2nd antennal joint, and pedicel and base of third yellowish-white. Fore-tibiae lighter grey-brown, excepting basally and along upper and lower margins, and extreme tips of hind- and intermediate-tibiae inclined to be light. Tarsi light grey-brown. Fore-wings including ciliae light greyish- or smoky-brown, spines black.

Head about 0.9 as long as broad, cheeks slightly swollen behind eyes and somewhat arcuate; surface irregularly and transversely striate. Eyes coarsely facetted occupying a little less than 0.5 the length of head, markedly pilose pigmentation black. Ocelli large, equidistant, posterior pair on a line drawn through posterior fourth of eyes; anterior ocellus protected by a pair of fairly long bristles. A series of setae on a line just behind eyes. Mouth-cone not quite reaching to base of prosternum. Maxillary palpi apparently 2-jointed, the

second being long and slender. Antennae 6-jointed, including a single-jointed style. Relative lengths of joints 1-4 as follows:—10 : 16 : 10 (with pedicel) : 19, and 5 and 6 together (distorted in the unique preparation) approximately 32; 3 much narrower than either 1, 2, 4, or 5, and 1 at least as broad as 2. 4 with a stout (and apparently double) trichome, and 5 with a transverse pale area; long dark bristles on inner side of 1 and encircling 2 to 4.

Prothorax about as long as head, transverse, 1.65 as broad as long, posterior margin depressed (as in *Thrips paludosus*, Bagn. and others); two long, stout bristles at each posterior angle which are about 0.7 the length of prothorax, and a series of 3 additional postero-marginal pairs, the inmost being the longest and about 0.4 the length of those at posterior angles. Surface somewhat sparingly furnished



Ceratothrips britteni, n. sp.
First four joints of left antenna, × c. 350.

with fine setae, mostly about 0.2 the length of the prothorax. Pterothorax broadest at juncture of meta- and mesothorax, where it is about as broad as long and 0.3 broader than the prothorax. Legs rather stout, hind pair longest; all femora and tibiae setose and hind tibiae in addition having the distal two-thirds within armed with a series of long, stout spines. Wings reaching to about the base of 9th abdominal segment. Fore-wing more than 12 times as long as broad through middle: costa with 22-23 setae; lower vein 11-12, the most distal being slightly remote; upper vein with a series of 3 near juncture with hind vein, and then a series in distal half, in one wing 7 (5 + 2) and in the other 8 (7 + 1).

Abdomen oblong-ovate, broader than pterothorax, broadening

gently to 4, 4-6 sub-equal, thence narrowing gently to 9, and then more sharply to apex. Apical bristles long and strong, those on 9 (excepting inmost pair) about as long as segments 9 and 10 together; those on 10 only slightly shorter. Posterior margin of 8th tergite minutely fringed, 9 with a pair of dorsal bristles about 0.4 the length of the postero-marginal ones, 10 divided above almost to base. Lateral abdominal bristles moderately long.

This species is easily separated from *C. trybomi*, Reut., by the coloration of the body and antennae, the chaetotaxy of the forewings and larger and broader basal antennal joint.

Type.—In Hope Collections, University Museum, Oxford.

Habitat.—One female taken by Mr. Britten (after whom I find pleasure in naming the species) in the flowers of Devil's Bit Scabious *Scabiosa succisa*), Great Salkeld, Cumberland (Sept. 16th, 1913), with numerous examples of *Physothrips vulgatissimus*, Hal. (*pallipennis*, Uz.), *Ph. atratus*, Hal., etc.

THE BRITISH SPECIES OF THE GENUS *TETRACANTHELLA* (COLLEMBOLA).

By RICHARD S. BAGNALL, F.L.S.

(With 9 Text-figures).

In 1891 Schött[1] described *Tetracanthella pilosa*, the type of a new genus, and figured it in 1893 in his *Zur systematik und Verbreitung Palaearctischer Collembola*. In 1900 Wahlgren[2] in a paper, *Collembola der Bären-Insel*, records as *T. pilosa* a somewhat similar insect, differing chiefly in the shorter, incomplete spring, to which Axelson[3] later gave the name of *T. wahlgreni*. At this time the genus was placed in either the Lipuridae (Aphoruridae) or the Poduridae, but research has shown its affinities with *Isotoma*, and the genus is now placed with *Anurophorus* in the Entomobryidae at the beginning of the Isotominae.

Dr. W. M. (Axelson) Linnaniemi describes the two species, *pilosa* and *wahlgreni* in his *Die Apterygoten Finlands*, II., and it should be remarked that though Schött in diagnosing the genus says, "Pili clavati in segmentis apicalibus stipati, in ceteris dispersi," and figures the insect with very pronounced clubbed hairs on the abdominal segments, the *pilosa* of Axelson-Linnaniemi possesses simple hairs.

For some time I have observed a *Tetracanthella* which occurs not uncommonly in *Sphagnum* on our northern moors and hills, and which on account of Schött's misleading figure I could not reconcile with *pilosa*. However on the appearance of the second part of Axelson Linnaniemi's splendid work on the Finnish Apterygota the species was readily identified with *pilosa* as diagnosed and figured by him, my examples agreeing perfectly in every detail. More recently, whilst collecting Thysanoptera in the neighbourhood of Oxford, I had the good fortune of beating out a second species of *Tetracanthella* from old sallow stems, which, even on the field, I concluded to be referable to the genus. This latter insect

[1] Entom. Tidskr., pp. 191-192.

[2] Bih. till K. Sv. Vet.—Akad. Handl., 26.

[3] Die Apterygoten Finlands, I, 1907,

differs considerably from the two hill forms, thus necessitating some slight modifications in our present conception of the genus. It is quite possible that some future worker may erect a new genus for its reception, but, remembering the extraordinary variety in the number of anal horns in *Tullbergia*, and the fact that at least one species of *Aphorura* possesses a spring, I hesitate to take this step.

Genus **Tetracanthella**, Schött.

Lubbockia, Haller, 1880; *Deuterolubbockia*, v. Dalla Torre, 1895.

On the field species of this genus, though somewhat reminding one of *Anurophorus*, are very distinct little creatures, glossy, bluish-grey with lighter markings, and slow in their movements. *T. pilosa* occurs in numbers in *Sphagnum*, wet moss, etc., on our northern moors and hills to a height of 2,500 feet or more, whilst *wahlgreni*, which is more of an alpine form than *pilosa*, will almost certainly occur on some of our higher mountains.

The following key will enable workers to readily separate the species :—

1. Spring present, small. Anal horns large, 4. Inner claw of foot present. Size 1.5-2.5 mm. 2

   Spring absent. Anal horns small, 2. Inner claw of foot absent. Size 1.3 mm. **T. oxoniensis**, n. sp.

2. Spring longer, with mucro (2 teeth); Dens and mucro together about 0.75 the length of manubrium. Inner claw not bristle-like, about 0.25 the length of the outer claw. . . . **T. pilosa** (Schött), Axels.

   Spring shorter, without mucro. Mucrodens not quite 0.50 the length of the manubrium. Inner claw produced to a bristle-like ending, about 0.50 the length of the outer claw. . . **T. wahlgreni**, Axels.

Tetracanthella pilosa (Schött), Axels.-Linnaniemi.

Figs. 1-4.

Syn. See Axels.-Linnaniemi, Die Apterygoten Finlands, II, p. 101.

Haller's *Lubbockia coerulea* (1880) is doubtfully referred to this species, whilst the *Tetracanthella alpina* (1901) of Carl is synonymous. By a *lapsus calami* I referred to this insect in the *Entomological Record* (xxv, p. 226) under the name of *Tetracanthella schötti*, Wahl., a lamentable confusion of names caused by a too complete trust in my memory.

The species is readily recognised by its completely developed spring, which is longer than in *wahlgreni*, and by the shape of the empodium or inner claw of foot.

British Distribution.

I first took the species in numbers in *Sphagnum* on Chapel Fell near St. John's Chapel in Weardale, Co. Durham, in June, 1910, and later took a single example with *Isotoma* sp. in a nest of *Formica rufa* near Corbridge-on-Tyne, Northumberland (vii-1910). In September of the same year the species was met with in fair numbers at

Figs. 1-4. *Tetracanthella pilosa*, Schött. 1, Lateral view of end of abdomen, *i.e.* segments IV and V (+VI), × c. 90. 2, Dorsal view of anal horns, × c. 150. 3, End of tibio-tarsus and claw, × c. 360. 4, Lateral view of furca or spring, × c. 210.

Figs. 5-6. *T. wahlgreni*, Axels. (after Axelson-Linnaniemi). 5, End of tibio-tarsus and claw, × c. 360. 6, Lateral view of spring, × c. 360.

Ravenscar, Yorkshire, where it occurred in *Hypnum* on the cliffs at 600 feet, and in *Sphagnum* on the moors at about 700 feet,[1] whilst in May of this year I found it plentifully on Cheviot peak (Northumberland) at from 1,500 to 2,500 feet.

The *Tetracanthella* sp. recorded by Mr. Evans from Scotland are almost certainly referable to this species.

Previously known from Sweden, Norway, Finland, and the Swiss Alps.

Tetracanthella wahlgreni, Axels.-Linnaniemi.

Figs. 5 and 6.

Syn. See Axels.-Linnaniemi, Die Apterygoten Finlands, II, p. 103.

This species is closely allied to *pilosa*, but may be readily separated by the short spring which is without true mucrones, and has the apical

[1] Some of these Yorkshire examples were submitted to Dr. Axelson-Linnaniemi and returned as *T. pilosa*, Schött.

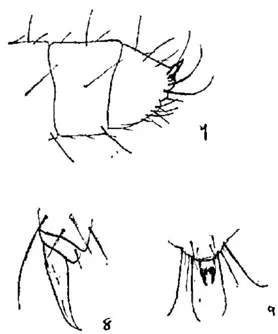
part (mucrodens) less than one-half the length of the manubrium, and by the bristle-like form of the inner claw.

It is an alpine species, rarer than *pilosa*, and is known from Sweden, Norway, Spitzbergen, and Finland. It will almost certainly occur on our Scottish mountains.

Tetracanthella oxoniensis, n. sp.

Figs. 7-9.

Form generally, and colour as in *pilosa*. Antennal joints 3 and 4 practically subequal. Upper claw without inner lateral teeth, inner claw absent, tibio-tarsus with one outer tenant hair. Spring apparently absent. Anal horns on elongated papilla, 2, approximate. Abdominal segment IV dorsally longer than either III or V (+VI). Length 1.3 mm.



Figs. 7-9. *Tetracanthella oxoniensis*, n. sp. 7, Lateral view of end of abdomen, *i.e.* segments IV and V (+ VI), × c. 90. 8, End of tibio-tarsus and claw, × c. 360. 9, Dorsal view of anal horns, × c. 150.

Type.—In Hope Collections, University Museum, Oxford.

Habitat.—In moderate numbers by beating dead sallow branches, near Kirtlington Park (Oxon.), September 21, 1913.

This species differs sharply from both *pilosa* and *wahlgreni* by the absence of the spring, the single pair of small, approximate, anal horns and by the absence of the inner claw of foot. The relative lengths of the antennal joints are 9: 15: 15: 23,—2 and 3 being subequal, whilst in *pilosa* 3 is distinctly smaller than 2.

The fourth abdominal segment in *pilosa* is shorter than V (+ VI), whilst in *oxoniensis* it is longer than either III or V (+VI).

OBSERVATIONS ON THE LIFE-HISTORY OF *USTILAGO VAILLANTII*, TUL.

By IVY MASSEE.

(WITH PLATE I.)

FROM a systematic standpoint this parasitic fungus has been known for some time. It was first described by Tulasne (1) in 1847; it has been recorded as occurring in the anthers or ovary of the following host-plants: *Gagea fascicularis*, Salisb., *Scilla bifolia*, L., *Urginea scilla*, Steinh., *U. anthericoides*, Steinh., *Muscaria comosum*, Mill., *M. botryoides*, Tausch., *Hyacinthus romanus*, L., *H. trifoliatus*, Tenore.

Its known distribution is as follows: Britain, Italy, Germany, Austria, Hungary, and N. Africa. It is highly probable that in the case of cultivated plants, its distribution is much more extended than is indicated above; for instance, so far as is known it is only met with on *Scilla bifolia* in Britain, an introduced plant. The following observations are based on material parasitic on *Scilla bifolia*, growing in the Royal Botanic Gardens, Kew.

MYCELIUM.

The mycelium is colourless, slender, from 1-6μ in thickness, sparingly septate and irregularly branched. At first it is intercellular, dissolving the pectin compound of the middle lamella, and forcing apart the walls of adjoining cells. At a later stage the mycelium penetrates the cell-walls, which appear to be dissolved by the tip of the hypha as in the *Botrytis* described by Marshall Ward (1*), and by this means spreads through the tissues. The hyphae were never observed to pass through pits in the cell-walls. When a seedling is infected the germ-tube of the spore enters along the line of the middle lamella and forms mycelium which passes into the tiny "cushion" or flattened stem at the base of the bulb, and it continues to increase in quantity as the stem increases in size, being most abundant towards the periphery. Numerous haustoria, formed of short, inflated branchlets crowded together and forming a botryoid mass, are present in the cells, agreeing

closely in structure with the haustoria of *Melanotaenium endogenum*, De Bary, and the haustoria of *Puccinia fusca*, Wint., and its aecidial condition (*Aecidium leucospermum*, DC.) as figured by Dowson. (2) When young and of functional value the haustoria are hyaline, very thin-walled, and stain very quickly with a watery solution of azol blue, before any other portion of the section has taken up the stain, thus becoming sharply differentiated. When old the walls of the haustoria become thicker, and tinged yellowish-brown, and are very conspicuous. At this stage they are of no functional value.

Hyphae from the perennial mycelium enter the flower-stalk immediately it is formed, and can be readily traced throughout its length, also in the pedicels, and the filaments of the stamens. On entering the anther the hyphae soon fill the cavities intended for pollen, and form numerous short branches, which in due course give rise to the spores. The course of development of the spores will be explained later. In rare cases the hyphae enter the ovary, and form spores in the ovules. The mycelium in the stem never passes into the roots, the substance of the bulb or the leaves. On the other hand, when a lateral bulb is formed the mycelium passes from the old stem into the young one, with which it is in organic contact. Tulasne (3) says that in *Muscari comosum* the spores are produced in the ovary and the anthers remain uninjured.

Formation and Germination of the Spores.

The vegetative mycelium is transversely septate, and each cell contains a single nucleus. Those portions of the mycelium which enter the anther-cells produce numerous short branches which are cut up into cuboid cells by transverse walls, each cell containing one nucleus: eventually alternate transverse septa deliquesce and disappear, thus leaving two nuclei in each cell. These nuclei fuse and form the single nucleus present in the mature spore. Soon after the fusion of the nuclei the wall of the mother hypha becomes swollen, and the protoplasm concentrates round the nuclei and forms the spores, which are fully grown while yet within the hyphal wall. Finally the deliquescent walls of the hyphae completely disappear, leaving a dry, dusty mass of spores. The epispore when first formed is perfectly continuous and slightly tinged with violet. It becomes darker in colour and rigid before the spore has attained its full size, and consequently is broken up into minute, irregularly polygonal portions, due to the continued increase in size of the spore which when mature averages 13-15μ.

When placed in a hanging drop in tap water the spores germinate, on the average, after two days, whether only one day old, or three months old, but to this general rule there are exceptions. Different cultures put up at the same time, from the same batch of spores, showed very marked differences in the time of germination. Sometimes practically all the spores in a culture germinated, and the hemibasidia became free from the promycelium, within twenty-four hours, while in another culture germination was delayed until the sixth day, and the hemibasidia were free on the seventh day. Again, in different cultures from the same batch of spores, under exactly similar conditions of treatment, some of the cultures produced only hemibasidia on germination, whilst in other cultures some spores produced hemibasidia while others bore chains of oidia as a direct continuation of the promycelium, which was often very much elongated. In these cases no hemibasidia were formed. The oidia became free and reproduced themselves copiously by budding, and large colonies of thousands of spores were produced in a culture. These budding spores were rarely observed to germinate; when this occurred the germ-tube again became broken up into oidia. (Pl. 1, fig. 24.)

Rarely a sterigma, instead of remaining short and bearing a normal spore, grows out into a long filiform branch which remains simple or becomes branched, and the tips of the branches break up into minute oidia. When the spores are put up in a decoction of prune juice the promycelia and hemibasidia are more robust than those produced in tap water.

On germination the promycelium varies very much in length, ranging between 80-200μ in the same culture. A terminal portion of the promycelium tube, of variable length, becomes swollen and narrowly fusiform, and is then cut off by a septum: this terminal portion, or hemibasidium, as a general rule breaks away from the promycelium at the septum, as previously pointed out by de Bary (4), and afterwards becomes 3-septate and constricted at the septa. Finally each cell gives origin to a short slender outgrowth or sterigma, bearing an elliptic-oblong spore, averaging 8-12 × 3-4μ. The apical cell of the hemibasidium usually bears the first spore, at or near the tip. As a rule a spore only gives origin to one promycelium tube: Brefeld (5) figures a spore producing two promycelium tubes, and in my cultures I have observed spores producing as many as four. Brefeld (5) has also figured cases where, after the first hemibasidium has separated from the promycelium, the latter has branched and produced a second hemibasi

dium; this was a common occurrence in my cultures, sometimes the promycelium sending out two or three branches each bearing a hemibasidium. The average size of a hemibasidium is $40\text{-}50 \times 5\text{-}8\mu$. It is not unusual for the hemibasidia to produce several spores in succession from the same sterigma: in fact, spores are produced until all the protoplasm contained in the cell is exhausted. No conjugation of the spores takes place in this species.

Infection Experiments.

Numerous attempts were made to infect the anthers, in some cases while they were quite young and in the unexpanded flower-bud, but always without success. The fact that infected plants produce flowers which are full of spores before the inflorescence appears above ground, proves infection of the flowers to have taken place underground.

My father who has been interested in this disease for many years, has already proved the presence of hibernating mycelium in the flattened stem of the bulb, and further observed that the same bulb produced smutted anthers annually.

This suggested the idea that the plant might possibly be infected in the seedling stage, as occurs in oats and certain other plants attacked by species of *Ustilago*. This idea proved to be correct. Very young seedlings of *Scilla*, planted in finely sifted soil, sterilised by steam, and afterwards intimately mixed with a copious supply of the *Ustilago* spores, were allowed to grow for three months. Examination of the stem or "cushion" of the bulb of these seedlings showed the presence of mycelium and the very characteristic haustoria. Seedlings grown under exactly similar conditions, except that no spores were mixed with the soil, showed no trace of mycelium in the stem. Seedlings placed in water in which germinating *Ustilago* spores were present also became infected. The germ-tubes of the promycelium spores appeared to be capable of entering the tissues through any colourless portion of the seedling, but not where chlorophyll was present. The entrance of the germ-tube was indicated by a minute yellowish spot on the surface, from which point the mycelium could be traced in the tissues, being clearly differentiated by a watery solution of nigrosin.

Bulbs which had produced flowers free from smut and were consequently free from the disease, did not become infected when grown in soil containing the *Ustilago* spores, thus proving that infection can only take place during the seedling stage. This explains why smutted flowers appear in the same bed as healthy flowers year after year, and

the latter do not become infected. Infected plants are, as a rule, more robust and somewhat larger than normal ones; and, with the exception of the anthers, the flowers are unchanged. Seeds are usually formed, and when this is not the case it is due to the dense mass of spores preventing pollen from reaching the stigma.

This work was done in the Jodrell Laboratory, Royal Botanic Gardens, Kew.

Summary.

All the host-plants of the fungus belong to the order Liliaceae.

The spores are only produced in the anthers or in the ovary.

Infection of the host-plant can only occur during the seedling stage. The mycelium hibernates in the flattened stem or "cushion," and grows up along with the flowering stem each year. Hence, when a seedling is infected, the resulting bulb is infected for all time. By the dispersion of infected bulbs, the spread of the disease has been effected in the case of cultivated plants.

The spores retain their vitality for at least three months, after being kept perfectly dry. The influences which respectively determine the production of a promycelium bearing a hemibasidium, or that of a slender germ-tube which becomes directly broken up into oidia, have not been determined.

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1. Tulasne.—Ann. Sci. Nat., series 3, 1847, p. 90.
1.ᵃ Marshall Ward.—Ann. Bot., 1889, 2, p. 319.
2. Dowson.—Geitschr. für pflanzenkr., 1913, 23, tab. 3.
3. Tulasne.—Ann. Sci. Nat., series 3, 1847, p. 91.
4. De Bary.—Compar. Anat. and Physiol. Fungi. Eng. ed., p. 195.
5. Brefeld.—Unters., 1895, 12, tab. 6, figs. 32-38.

EXPLANATION OF PLATE I.

Illustrating Miss Ivy Massee's paper on the "Life-history of *Ustilago vaillantii*, Tul."

Fig. 1. *Scilla bifolia*, showing infected anthers; nat. size.
Fig. 2. Flower of same, with infected anthers; slightly mag.
Fig. 3. Fragment of vegetable mycelium; highly mag.
Fig. 4-5. Terminal branches of mycelium from the anthers, showing various stages of spore-formation; highly mag.
Fig. 6. Haustoria in cells of flattened stem or cushion of bulb; highly mag.
Fig. 7. Haustorium in a cell of the pedicel of a flower; highly mag.

Fig. 8. Portion of mature epispore, broken up into irregularly polygonal patches; highly mag.

Fig. 9. Mature spore; highly mag.

Figs. 10-12. Spores germinating and producing hemibasidia; highly mag.

Figs. 13-19. Spores producing secondary hemibasidia after the first hemibasidia have become free; highly mag.

Figs. 20-21. Hemibasidia, which have become free, in various stages of development, some producing spores; highly mag.

Fig. 22. Spores free from the hemibasidia; highly mag.

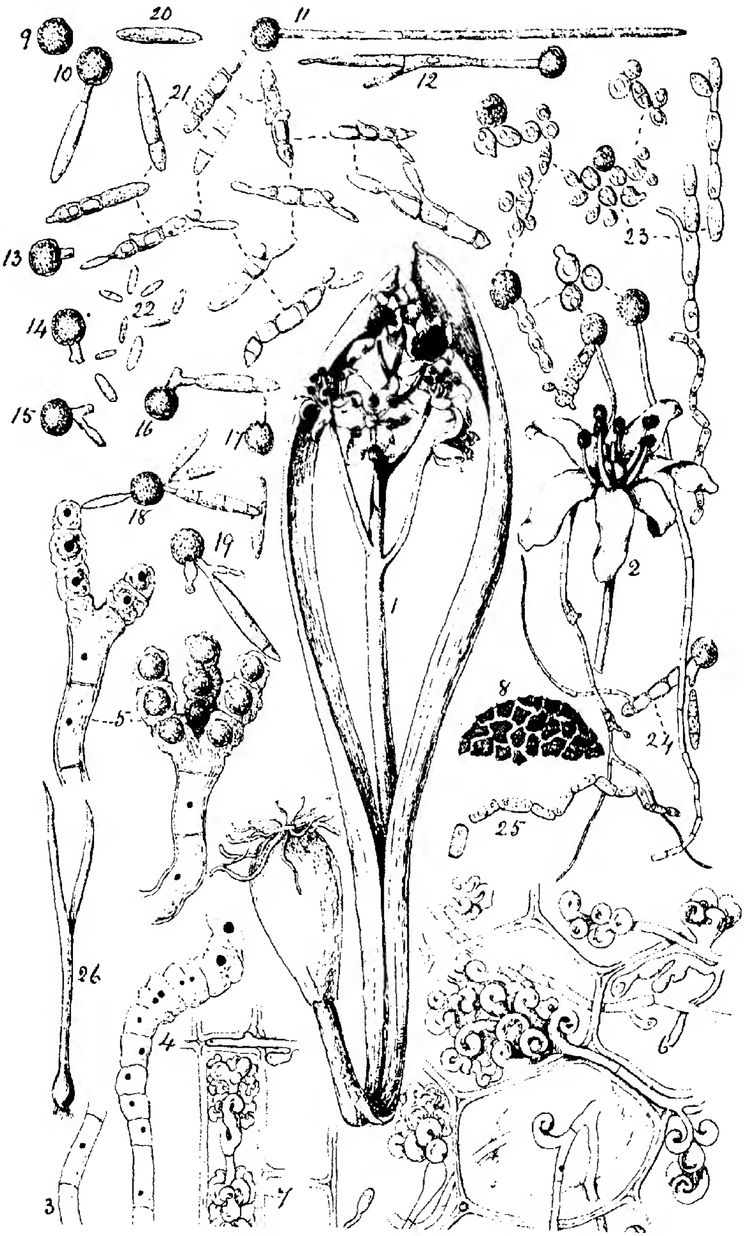
Fig. 23. Spores germinating and producing oidia directly instead of bearing hemibasidia; highly mag.

Fig. 24. Spore bearing a short chain of oidia, the terminal one of which has produced a slender hypha; the basal oidium has given origin to a hemibasidium; highly mag.

Fig. 25. A typical chain of oidia which has become free; highly mag.

Fig. 26. Seedling of *Scilla bifolia* at about the stage when infection occurs.

Fig. 27. A germinating spore entering the tissues of a seedling; highly mag.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SOME NOTES ON THE TERRESTRIAL ISOPODA.

By P. A. AUBIN, F.R.M.S.

(With 2 Text-figures).

The following notes which, so far as I am aware, are original, record, I believe, some hitherto unnoticed points in connection with this interesting family.

Though the observations have been made principally on *Porcellio scaber*, Latr., and *P. laevis*, Latr., they apply equally to *P. dilatatus*, Brandt, *Porcellionides pruinosus*, Brandt, *Trichoniscus roseus*, Koch and *Oniscus asellus*, L. No other species have been observed up to the present.

Antennae. In addition to being the bearers of sense organs, the antennae are also used as weapons; thus specimens of *Porcellio* may be seen with their frontal lobes in contact striking each other with their antennae. For this purpose the flagellum is bent at right angles to the peduncle, and the blow is struck with the point of the terminal spine. The action is quite distinctive, and cannot be mistaken for the ordinary movements of the antennae.

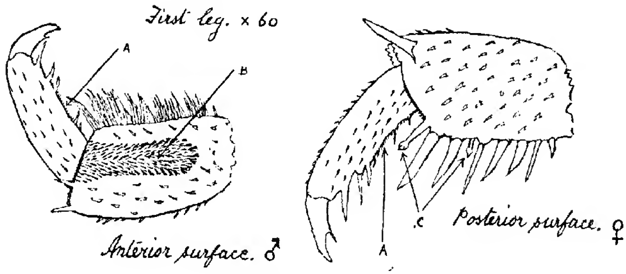
A further action has been observed on several occasions which tends to show not only that the antennae are modified legs, but, also, that the modification has not proceeded sufficiently far to obliterate entirely the ambulatory function. Oniscus, if confined in a Petri dish with sides of such a height that whilst the specimen cannot reach the top with its feet, it can do so with its antennae, will hook the flagellae over the edge and attempt to pull itself up.

Legs. There is a marked difference between the sexes in the arrangement and nature of the spines on the posterior edge of the legs. The accompanying sketch of the three distal joints of the first leg of *P. laevis* shows this clearly. In the upper figure, from a male specimen, the spines are very numerous, fine and closely set, and may be described as brush-like; in the lower figure, from a female, they are coarse, set far apart and comb-like. Further, the bulbous spines shown at C. are always present in females, but their situation does not

appear to be very definite. This sexual difference applies to all the legs.

A definite portion of the first pair of legs, shown in A. and B., is highly specialised to provide for the cleaning of the antennae. This consists of (A) a fine comb-like arrangement of spines on the inferior edge of the propodite, and (B) a groove of varying depth on the anterior surface of the carpopodite. This groove is bounded over most of its periphery by a row of slighly recurved spines, whilst the whole area of the groove itself is closely beset with fine hair-like spines. It is somewhat difficult to make out this structure in unprepared material, but it is easily demonstrated by treating a fresh specimen with one of the intra-vitam stains, possibly best of all a very dilute aqueous solution of neutral red.

This cleaning apparatus is used in three different ways: (1) the



Porcellio laevis, Latr.

flagellum is grasped between the comb A. and the long spines at the distal end of the carpopodite and drawn between the two; (2) the front leg is held forward, the flagellum is laid in the groove and the leg is thrust forward so as to stroke the flagellum; (3) the leg is held forward, the flagellum is bent to an acute angle with the peduclc, it is then laid in the groove and the stroke made with the antenna, the leg remaining rigid. It will be seen that (2) and (3) clean opposite sides of the flagellum.

The first pair of legs are also used for other than locomotive purposes; thus, small particles of food are held down, or the particle may be clasped between the claws and held up to the mouth; food is carried by being grasped between the carpopodites, where it is apparently held by the spines on the periphery of the above-mentioned grooves. They are used, in conjunction with the second pair, to dis-

integrate large pieces of food, the claws of first pair being hooked into a particle, the second pair of feet are placed against the mass and the particle is torn off by a combined retraction of the first pair and an extension of the second pair.

All the legs are cleaned by stroking them with the spined edge of an adjacent pair.

The long, stiff spines (D) at the distal end of the propodite, and the fact that the dactylopodite can be brought into apposition with them or between them, is very suggestive of a grasping organ like that of *Palinurus*. I have, however, been unable to detect such use.

Ecdysis. From such literature as I have been able to consult, this interesting process appears to have been dealt with very inadequately, and the following record of observations on *Porcellio laevis* and *P. dilatatus*, whilst not professing to be complete, gives some additional details.

Ecdysis is extremely common in early Spring, and it is quite an easy matter to observe the process in detail with captive specimens.

The process commences with a general listlessness, and the animal may in some cases, but not the majority, try to hide; some 20 to 24 hours later the posterior tergal joints are distinctly gaping, and the connecting integument is of glass-like brilliancy, a faint white line is visible at the extreme edge of pleura and along the posterior edge of terga; five hours later the three posterior thoracic and all the abdominal segments have become quite white, the last three pairs of legs are not used but are dragged uselessly along the ground; the front of the fifth segment is just showing at the fracture of the old shell; droplets of liquid exude at the fracture, and close examination shows that there is a film of liquid interposed between the old shell and the underlying cuticle; the animal makes constant efforts to free itself, manifested by a rhythmical elongation and contraction of the body, noticeable more especially between the fourth and fifth segments; these contractions continue throughout the process of ecdysis and for some time after. An hour later the whole of the fifth segment is exposed, except the points of the pleura, which are folded back and still held by the edge of the old shell; ten minutes later half of the sixth tergum is showing, and the points of the fifth pleura are free; the tail-appendages are entirely withdrawn from their old shell, and the legs are so far withdrawn that the extremities occupy the centre of the carpopodite of the old shell. The ecdysed portions participate in the contractions, and the worm-like undulations distinctly show

that the new cuticle is soft; five minutes later the whole thorax is free as well as the pleura of the third abdominal segment, and in a further five minutes the animal crawls free. At this time the posterior segments are still narrower than the anterior ones; but the contractions continue at the rate of about two per minute, and in the course of about half an hour the soft posterior half of the body has become wider than the anterior half (except in the case of full-grown specimens) and the animal crawls about, slowly using the anterior legs only. The new cuticle has now lost its glossy appearance and become smoky. It may therefore be said that the increase in size of the animal takes place gradually in the short period between the moment of ecdysis and the solidification of the new shell.

The animal remains quiescent for two or three hours, when it will begin to use the posterior legs; at first it appears to try their strength by supporting the body on them and raising the four anterior pairs of feet from the ground, and at the same time curving the anterior segments upwards.

The tail-appendages play a distinct part in ecdysis; when the process is sufficiently advanced, it can be observed, through the shell, that with each contraction of the body they move forward with their upturned points resting against the interior surface of the old shell, and with the following elongation they retain their position and the shell is moved backward.

Specimens frequently examine the cast shell, but make no attempt to eat it, though it is often eaten by other individuals.

Some two to four days after the moult of the posterior half is completed, the animal becomes inactive and begins to show the same preliminary whitening of parts of the anterior portion of the body, the first part to whiten being the flagellum; the joints of the carapace begin to gape, showing the glossy connecting integument; the legs of the anterior segments as well as the antennae are directed forwards.

Twenty-four hours later, expansion and contraction of the body begins, each contraction being accompanied by a strong downward bending of the posterior half of the body. Shortly after the commencement of these contractions the eyes and lobes lose their colour and become semi-transparent; the limbs and antennae become useless and do not respond if touched.

If, after the contractions of the body have continued for about an hour, the specimen be examined under a strong light, it will be found that although there is as yet no sign of the terga having moved

within the old shell, the antennae have been withdrawn to such an extent that the flagellae occupy the distal two-thirds of the first joint of the peduncle, and that the legs have been withdrawn nearly three joints within the old shell. The flagellae gradually become more visible within the peduncle owing to a gradual resumption of colour.

After a variable period of effort the edge of the fourth tergum appears from beneath the old shell, and the same phases are gone through as in the case of the posterior half of the body; all the legs are freed practically simultaneously when the free edge of the old shell reaches the level of the eyes, but as soon as the proximal joints are clear they are used to push the shell forward; the spines along the legs engaging with the free edge of the old shell of the fourth sternum for this purpose.

After the feet are free the shell is still pushed forward with the antennae; the first joints of the peduncle being in contact along their whole length and resting against the inside of the old shell in the median line, the more proximal joints are used after the fashion of lazy-tongs; as soon as the peduncles are entirely clear of the cast shell the flagellae are freed by a sudden separation of the antennae, which are at once folded back so that the flagellae rest, along their whole length, against the head and first tergum with the points directed upwards. Except for the contractions of the body, the animal remains motionless for some minutes, and then begins to walk with a peculiar gait—the anterior four pairs of legs being still soft it uses only the fifth, sixth and seventh pairs, with the result that it overbalances at every step and falls forward so that the metastoma strikes the ground.

The point I would emphasize is that throughout the whole ecdysis there is no such thing as *crawling out of the shell*; with the exception of the moment when the last abdominal pleura are freed and a slight forward movement is made to free the tail-appendages, the animal remains stationary, and the shell being cast is pushed forward or backward as the case may be; this even applies to the clearing of the greater portion of the antennae as described above.

At the moment of ecdysis there are no joints properly so-called between the terga, the connecting integument being continuous from the posterior edge of one tergum to the anterior edge of the succeeding one; the infolding of the integument to form the normal joint is not complete until half an hour after complete ecdysis, and the joints appear to infold in the order of their emergence from the old shell.

In some cases, at the period when the legs and antennae are with-

drawn within the old shell before the terga have moved, the extremities are eaten by other woodlice and the individual so attacked dies, being unable to complete ecdysis. This is due to the soft extremities being injured, and the coagulation of the exuded blood, by fastening the limb to the shell, prevents further withdrawal.

Though such is stated by several writers to be the case, I have never observed any attempt on the part of other individuals to eat the soft parts of a newly ecdysed specimen; the latter, however, objects to such parts being touched.

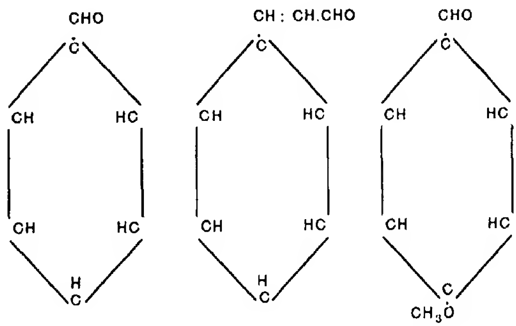
Intelligence. The following observation appears to indicate a process of reasoning which can hardly be attributed to instinct. For ease of observation I keep specimens in shallow, glass-topped boxes; when a fresh batch are introduced it is almost impossible to prevent their escaping in all directions if the cover is lifted; after a few days, however, the cover may be removed for quite an appreciable time, and hardly a single specimen will crawl up the side of the box; they appear to have realized that there is no escape in that direction.

A TRAP FOR THRIPS.

By F. M. HOWLETT, B.A., F.E.S.,

Imperial Pathological Entomologist, India.

In the course of some experiments on the degree of attraction of some chemical substances for flower-haunting insects, I recently observed that three of these substances have a very marked attraction for Thrips. The attraction is indeed strong enough to suggest that the observation may be of value as providing a simple means of destroying the insects in quantity. The three substances are all Aldehydes of similar composition, *Benzaldehyde*, *Cinnamylaldehyde*, and *Anisaldehyde*, with the following structural formulae:



Benzaldehyde. *Cinnamylaldehyde.* *Anisaldehyde.*

Another aldehyde, Salicylaldehyde, was found also to be not unattractive.

The experiments have been tried in November and December, and Thrips is at this season far from abundant. It seems not improbable that much larger catches of the insects will be made when the weather becomes warmer and more favourable, and I have for this reason thought it worth while to publish the not very imposing record to date, in the hope that it may perhaps prove of some utility to horti-

culturists and others interested in the destruction of Thrips. Anisaldehyde and Cinnamylaldehyde can be bought for eight or ten shillings a pound, but Benzaldehyde (pure) costs under two shillings: taking the same quantity as was used in my experiments (about 2 grammes), a pound would be enough for about 200 traps, which would probably retain their efficiency for at least a week, and possibly much longer if a better form of trap is devised. To prevent possible oxidation of the aldehyde it might be well to add a trace of Formaldehyde, which is likely to have little effect on the efficiency of the trap, but it is now too late in the season for testing the effect of this addition here.

Two varieties of Thrips were caught, one with a fulvous head and thorax and blackish abdomen (A), and the other palish yellow (B); neither are identified. They appeared to be all females, but of this I cannot be quite certain. The method adopted was to expose small bowls, each containing about half-a-pint of water with 2 cc. of the aldehyde stirred up in it. The insects attracted are drowned in the water. Better methods of trapping could probably be easily devised.

The first experiment was as follows:—

(1) 1.ix.13. 6.0. a.m. Exposed bowl of Cinnamylaldehyde Merck.
1.0. p.m. Between 100 and 150 Thrips *A*.
2.ix.13. 1.0. p.m. Over 300 Thrips *A*.

After this date I was unable to continue the observations until November, when Thrips was getting scarce.

(2) 9.xi.13. 1.0. p.m. Exposed following aldehydes, and inspected for Thrips

Number of Thrips seen at

	11 .a.m. 10.xi.13,	9 a.m. 12.xi.13,	& 10 a.m. 20.xi.13.
Isobutylaldehyde	2 A 2 B	2 A 2 B	(smell gone).
Salicylaldehyde	10 A 8 B	20 A 8 B	(smell faint).
Anisaldehyde	5 A 30 B	(a crow upset the bowl).	
Cinnamylaldehyde	10 A 4 B	60-80 A 30-40 B	100 A 40 B
Benzaldehyde	15 A 2 B	60 A 8 B	80 A (6) B

(3) 10 a.m. 12.xi.13. Mixed 1 cc. *Benzaldehyde* with 1 cc. *Cinnamylaldehyde* in 10 cc. alcohol, and exposed in a pint of water in bowl.

After	5 minutes	exposure,	0	Thrips.
,,	25 ,,	,,	1	,, *(A)*
,,	50 ,,	,,	5	,, ,,
,,	2 hours	,,	13	,, ,,
,,	8 days	,,	290-300	,, ,,

(4) 10 a.m. 10.xii.13. Exposed following bowls: inspected at

	6 p.m. 10th.	10-30 a.m. 11th.
(a) *Benzaldehyde* and water	0	0
(b) *Benzaldehyde* and dil. formalin.	0	0
(c) Dilute Formalin.	0	0

It seems probable from this last experiment that Thrips is now (December) absent or inactive, and that the November catches were made at the end of the season of activity, and were thus naturally small. I propose to resume operations at the beginning of the warm weather, and to experiment with Nitro-benzene, a substance which does not contain the aldehyde-group (CHO), but has a smell closely resembling that of Benzaldehyde. It should be then possible not only to obtain more evidence as to the practical economic value of the method, but by employing Nitro-benzene to ascertain also whether the attractiveness is bound up with the presence of the aldehyde-group, or whether the insect's olfactory sense is, like our own, similarly affected by Nitro-benzene and Benzaldehyde.

PRELIMINARY STUDIES ON THE BIOLOGY OF THE BED-BUG, *CIMEX LECTULARIUS*, LINN.

III. FACTS OBTAINED CONCERNING THE HABITS OF THE ADULT.*

By A. A. GIRAULT,

The University of Illinois.

INTRODUCTION.

IN this concluding paper of the series of three upon this insect, I shall give a narrative account of pairs mating in confinement, adding occasional comments.

NARRATIVE ACCOUNT OF MATING PAIRS KEPT IN CONFINEMENT.

1. *A First Generation.* This generation has already been noticed in the first and second parts. It originated from a single female partly fed, captured from a berth in a stateroom of a steamboat plying between Cincinnati, Ohio, and Louisville, Kentucky, near midnight, August 7th, 1907. This female was confined at once in an ordinary physician's pillbox and left without food. On August 26th it died after laying ten eggs. These latter hatched at noon, August 27th, and were reared to maturity as described in Part I. The following matings were effected between the mature bugs:

(1) *Pair No. 1.* After a full meal[1] on human blood at 8 p.m.,[2] at 9.30 p.m., December 19th, 1907, adults No. 2 (larger) and No. 4 (smaller) were confined together in a flat cardboard box, three inches long, three quarters of an inch high and two inches wide, containing a few strips of coarse paper. They had been fed previously on the same kind of blood, No. 2 on November 24th (15 minutes);[3] No. 4 on November 1st

*Part II appeared in this Journal, 1912, vol. vii, pp. 163-188.

[1] All of these pairs were fed on human blood, usually at night near an electric light, feeding was usually accomplished by baring the arm, placing the fore arm across a clean sheet of paper and tilting the box confining that pair against the naked flesh at a place (lower fore arm) where there is little or no hair. Upon responding to the stimulus, the bugs would run up the sides of the containing box and insert the setae.

[2] Five and a half minutes of actual; one and a half minutes for insertion.

[3] Plus four and a half minutes for insertion of the setae.

[JOURN. ECON. BIOL., March, 1914, vol. ix, No. 1.]

and 24th for ten and eleven minutes,[1] respectively. The two bugs were not observed to mate, though they remained near each other. Consequently, on December 22nd, No. 4 was removed (it proved to be a female) and adult No. 3 added (9.30 p.m.). After a few minutes the latter approached the larger No. 2 and climbed upon its back, acting as though desirous of mating. No. 3 had been fed previously on November 24th (6 minutes) and December 19th (6 minutes). They were not further observed until 12.45 a.m., December 31st, when both were offered food; No. 2 gorged itself,[2] but No. 3 obtained only part of a full meal; after feeding, No. 3, a male, was again observed to climb upon the back of No. 2, a female. After several minutes the latter dislodged her mate. Food was again offered at eight o'clock, January 9th, 1908, but the meal was interrupted. At 7 a.m., January 10th, ten freshly deposited eggs were found; they proved to be fertile, and mating had doubtless occurred. Thereafter, oviposition with this pair occurred as follows, all the eggs being fertile.

Jan.	10	7 a.m.	10 eggs	Jan.	22-24		18 eggs
,,	10	noon	1 ,,	,,	24-25	night	3 ,,
,,	10	4 p.m.	1 ,,	,,	25	3 p.m.	2 ,,
,,	11	6 a.m.	3 ,,	,,	25	10 p.m.	2 ,,
,,	12	,,	2 ,,	,,	25-26	night	1 ,,
,,	12-13	night	6 ,,	,,	27	a.m.	1 ,,
,,	13-14	,,	6 ,,	,,	27-28		3 ,,
,,	14	9-30 a.m.	2 ,,	,,	28	late p.m.	1 ,,
,,	14	7 p.m.	2 ,,	,,	29-30	night	5 ,,
,,	15	3 a.m.	1 ,,	,,	31	3 a.m.	1 ,,
,,	15-16	night	2 ,,	Feb.	1	by 6 a.m.	8 ,,
,,	17	4 p.m.	2 ,,	,,	1	6 p.m.	3 ,,
,,	18	4 a.m.	3 ,,	,,	2-3	night	3 ,,
,,	18-19	night	2 ,,	,,	4	2 a.m.	3 ,,
,,	19	7 p.m.	1 ,,	,,	6	4 a.m.	1 ,,
,,	19-20	night	4 ,,	,,	7-15		1 ,,
,,	20	noon	1 ,,				
,,	20-21	night	4 ,,			Total	109 eggs

The pair were offered food by tilting the edge of the box containing them against the fore arm at 10 a.m., January 10, 1908. The male was then on the side of the box opposite to the female which was nearest to the food, but after the latter commenced to feed, the male crossed over, climbed on her back and took food from that position. The female fed for ten and a half minutes,[3] the male for about six. When repleted, the female left, necessarily disturbing the male, which was

[1] Nine minutes actual feeding, two for insertion.

[2] Nine and a half minutes feeding, one minute for insertion.

[3] Plus two more minutes for insertion of the setae.

probably not fully fed. Immediately after leaving food, the female voided two drops of excrement (each drop about 1.5 mm. diameter), and after several minutes another about the same size. This excreted matter was of the colour and consistency of watery black ink, and when voiding it the female makes a characteristic movement described later. On January 12th it was noted that the pair were constantly together, the male on the back of the female. Mating had not been observed. The female was fed at 4.30 p.m., January 14th until nearly glutted,[1] and again at 9 p.m. the same day; at neither time did the male approach the host. Again at 7.20 p.m., January 18th, the female fed until satisfied,[2] and at the same hour the following day[3]; on this occasion the male partly fed itself.[3]

When both sexes were full fed, the female was twice as large as her mate. On January 19th the female fed for six minutes, though within twenty-four hours of a previous meal; she did not, however, respond as quickly as usual to the food stimulus. At the same time the male succeeded in obtaining part of a meal; he was disturbed by the female. At 9.15 p.m., January 25th, the female remained at food for ten and a half minutes, including insertion, becoming glutted; and the male for five minutes at 10 p.m. The latter was shy and induced to take food only when in almost complete darkness. At 10.30 p.m., January 27th, upon lifting the lid from the confining box, the pair were found apparently mating, end to end. Before this could be determined with certainty, however, they separated (presumably because of the sudden exposure to the bright light). The female died on February 15th. The male was fed and confined with adult No. 9 at 8 p.m., February 18th, constituting pair No. 3.

The female of this pair hatched at noon, August 27th, 1907, reached maturity at noon, October 30th of the same year, after having been given eight full meals. She was fed for the first time, after maturity, nearly a month later (November 24th), and was mated on December 22nd, after having been fed once more. About twenty days after being mated she began to lay fertile eggs, continuing nearly regularly to do so until her death on February 15th. A hundred and nine eggs were deposited in a period of thirty-six days, or about three per day. The history of the male is summed up in connection with pair No. 3.

(2) *Pair No. 2.* Adults Nos. 1 and 4 were placed together on

[1] Nine and a half minutes of actual feeding.

[2] For seven minutes, including insertion.

[3] For six minutes including insertion.

strips of paper laid side by side in a circular wooden box (about twice the depth of an ordinary pill-box) at 6.30 p.m., January 19th. No. 4 being small was supposed to be a male, and had been confined with adult No. 2 of the first pair (which see); subsequently, it had been isolated and was fed on January 12th at 2 p.m. Adult No. 1 had been isolated from maturity; it had fed previously on November 1st (10 p.m., 6 minutes), November 24th (11.30 a.m., $5\frac{1}{2}$ minutes), and December 19th (9 p.m., $5\frac{1}{2}$ minutes feeding, 3 minutes insertion). As soon as placed together the two females were shaded from the electric light; after remaining quiet for two minutes No. 1 moved over to No. 4, and climbed upon its back and then off again; No. 4 then crawled upon No. 1. These movements were continued for several minutes, No. 4 generally climbing on to No. 2. From these actions, which are known not to have any sexual significance, since both were females, it would seem that bedbugs recognize each other and are not adverse to company.

On January 25th, 9.40 p.m., under equal chances, the adult No. 1 fed until satisfied for five minutes, including insertion, but No. 4 refused food. However, at 10.20 p.m., No. 4 fed for six minutes, when placed in nearly complete darkness and exposed to the stimulus for some time (compare the actions of the male in pair No. 1), No. 1 also went back to food for one minute. At 7 p.m., February 18th, food was again offered, and No. 1 immediately accepted, becoming gorged after some minutes; No. 4 after several minutes rapidly ran to the food (fore arm placed over the edge of the box), disturbed No. 1, ran back to bottom of box and after remaining perfectly quiet for about a minute, again rapidly ascended and began to feed (before No. 1 had finished); it gorged itself. Again at 8 p.m., February 23rd, food was offered and No. 4 soon accepted and gorged itself, reversing its former behaviour, which was taken by No. 4 this time; for the latter did not respond positively to the stimulus at all, appearing to be very shy. However, at first, No. 4 also hesitated; both, in fact, at first ran nervously backwards and forwards. Thirty minutes later food was again offered upon which No. 1 cautiously[1] approached, remained a minute inserting its setae, but suddenly left.

Being convinced that both of these adults were females, at 8.30 p.m., February 23rd, 1908, adult No. 6, a male, was added to the box. Fifteen minutes later it was found (apparently) mating with No. 1, and five minutes later it attempted (apparently) to mate with No. 4; the latter was immediately removed and isolated in a vial. Both

[1] Certainly cautiously is the word; bedbugs are negatively phototropic.

females began to deposit fertile eggs on February 27th; adult No. 4 was therefore fertilised by adult No. 6. Nos. 1 and 6 constitute this pair, the female of which deposited eggs at the following times:

Feb.	27	early a.m. - -	3 eggs	Mar.	26-27	night - - -	3 eggs
,,	27	11 a.m. - -	1 ,,	,,	27-28	24 hours from 8 a.m.	1 ,,
,,	28	4 a.m. - -	2 ,,	,,	29	3-8 a.m. - -	1 ,,
,,	28	5 30 p.m. - -	1 ,,	,,	29-30	24 hours from 8 a.m.	2 ,,
,,	29	6.30 a.m. - -	3 ,,	April	2-3	night - - -	1 ,,
,,	29	2.30 p.m. - -	2 ,,	,,	3-4	24 hours from p.m.	5 ,,
Mar.	1	early a.m. - -	3 ,,	,,	4	10 30 p.m. - -	3 ,,
,,	1 2	night - -	1 ,,	,,	5	4 a.m. - - -	1 ,,
,,	1	early a.m. - -	1 ,,	,,	5-6	night - - -	3 ,,
,,	4	4 p.m. - -	1 ,,	,,	6-7	,, - - - -	3 ,,
,,	6	early a.m. - -	3 ,,	,,	7-8	,, - - - -	4 ,,
,,	6	noon - -	1 ,,	,,	8	p.m. - - -	1 ,,
,,	7	2 p.m. - -	1 ,,	,,	8-9	night - - -	2 ,,
,,	7	11 p.m. - -	2 ,,	,,	9	p.m. - - -	1 ,,
,,	8	4-30 a.m. - -	4 ,,	,,	9-10	- - -	2 ,,
,,	8-10	- -	6 ,,	,,	13	4-9 p.m. - -	1 ,,
,,	11	- -	1 ,,	,,	16	2-5 a.m. - -	1 ,,
,,	11-12	night - -	2 ,,	,,	16	p.m.-April 18 p.m.	6 ,,
,,	12	- -	1 ,,	,,	18-20	p.m. to p.m. -	2 ,,
,,	13	- -	3 ,,	,,	20-21	24 hours from p.m.	4 ,,
,,	14-15	24 hours from a.m.	11 ,,	,,	21-22	,, ,, ,,	1 ,,
,,	15-16	p.m. to p.m., 24 hours	4 ,,	,,	23-25	- - -	4 ,,
,,	16	10 p.m. - -	1 ,,	,,	25-26	24 hours from p.m.	3 ,,
,,	16-17	p.m. to p.m., 24 hours	2 ,,	,,	26-27	,, ,, ,,	3 ,,
,,	19	8 9 p.m. - -	3 ,,	,,	27-28	,, ,, ,,	3 ,,
,,	20	3 a.m. - -	4 ,,	,,	29-30	,, ,, ,,	2 ,,
,,	20	p.m. - -	1 ,,	,,	30-May 4	- - -	7 ,,
,,	20-21	night - -	3 ,,	May	4-12	- - -	11 ,,
,,	21-22	24 hours from a.m.	3 ,,	,,	23-27	- - -	10 ,,
,,	23	- -	1 ,,	June	20-24	- - -	13 ,,
,,	24	- -	2 ,,				
,,	24-25	24 hours from 9 p.m.	4 ,,			Total	190 eggs
,,	25-25	night - -	5 ,,				

Of these hundred and ninety eggs all were fertile, except the last thirteen (June 20-24th), which failed to hatch. This fact is surprising, but the male had died two months previously and the final infertility of the female may be the more easily understood by reading the paragraphs concerning adult No. 4, added as a supplement to this pair.

The female of this pair was gorged with food at 8 p.m., March 7th, the male then refusing; however, at midnight, it finally accepted food after some hesitancy, the female leading the way for the second time and feeding again for about one and a half minutes; the male then quickly gorged itself. The male was also fed at 6 p.m., March 1st. Again the female gorged itself on March 15th at 8.10 p.m., the male then refusing until food was again offered at 8.30 p.m., when, after some minutes, it responded to the stimulus and gorged itself. Upon

leaving the host, it went immediately to the female and mated (in the dorso-lateral position upon the female's back). Both were fed until glutted at 8.35 p.m., March 20th, the male as usual responding positively to the stimulus about twenty seconds later than the female, and occupying less time for engorgement and leaving sooner. At 2 a.m., March 29th, the female again fed for over twelve minutes, its mate not responding to the stimulus. The next day at 8 p.m. the male was again exposed to food, but again did not respond; the female, however, seemed eager to feed, but was prohibited. There appears to be quite a difference between the sexes in regard to appetite (compare pair No. 3 this date; but also compare the two females in No. 1). April 4th at 9.55 p.m., the female gorged itself, feeding for five minutes; at the same time, the male responded to the stimulus but did not approach the host. At 9.15 p.m., April 12th, the female fed for seven and a half minutes, in full glare of the electric light; the male for ten minutes, but feebly, not appearing to be able to extract much food, its body remaining flat but becoming tinged, slightly reddish. The body of the female was flat before feeding. The male died on April 18th, still coloured. It had not had a full meal since March 20th. This male hatched at noon, August 27th, 1907, came to maturity January 9th, 1908, after having been fed (not at any time to repletion) nineteen times; after maturity it was fed, in addition to the times recorded above, at noon, January 12th (engorged); 6 p.m. January 29th; 7 p.m. February 18th; 7.30 p.m. February 23rd, just before mated, and at 6 p.m. March 1st.

On April 20th, 10 p.m., the female, now alone, responded almost immediately to food and fed for ten minutes; afterwards, she at once expelled excrement. And again at 10.20 p.m., April 28th, it accepted food after forty seconds, glutting itself, feeding for seven and a half minutes. It was necessarily neglected after May 6th on account of illness, but at 8.45 p.m., May 16th, it was still alive though obviously rather weak yet still active and full coloured. It accepted food at once, feeding until satisfied (engorgement), and for eight and a half minutes, having no difficulty in inserting the setae. Oviposition was checked, and no eggs were deposited during the four or five days, since all progeny present in the box with her were all nymphs. Not until June 11th was another meal given. Then at 10.50 p.m., it responded to the host, feeding to engorgement and for eight minutes, plus five minutes for various attempts to insert the setae, there being much difficulty in this respect; the female was still normally dark but sluggish in movement, and no eggs had been deposited since May

27th. Nearly a month later, June 20th, a few *infertile* eggs were deposited, and on June 24th thirteen of these were removed.

At 12.21 a.m., July 4th, the female still full coloured was exposed to food by tilting the box containing it against the under portion of the fore arm; it responded (by a quick, short movement) at 12.24, going to the food at 12.25 and feeding for fifteen and a quarter minutes until enormously swollen; apparently there was no difficulty with insertion. At 12.55 a.m. the same day, the very small adult No. 10 (a male) was placed with her after having been fed (see pair No. 4); after three minutes, the two were together, the male upon the back of the female but not mating. However, later, at 1.45 a.m., they were evidently mating, as the extremity of the abdomen of the male stretched when separating from the female when the box was opened (at least, attempting to mate). The male was removed at 10 p.m., July 4th, to its original box. I did not observe it to have any further relations with this female, though such may have occurred.

The female deposited no more eggs. It was allowed to engorge at 8.45 p.m., July 20th, and without receiving more food, died on August 10th, 1908. Like the others, this female hatched at noon, August 27th, 1907, came to maturity at noon, October 30th of the same year, after having received eight full meals, was fed for the first time two and a half days after reaching maturity, but not mated until February 23rd, 1908, or over three and a half months after reaching maturity. It then deposited a hundred and ninety eggs in a period of nearly four months, or on the average about 1.6 eggs per day; fertile eggs were deposited for slightly over three weeks after the death of the male. Oviposition commenced four days after mating.

Supplement to Pair No. 2.—Adult No. 4. The history of this female is given in connection with the first two pairs. Its small size was the cause of its being mistaken for a male. It was fertilised by adult No. 6 on February 23rd, 1908, then depositing eggs as follows. No male present.

Feb.	27	early a.m.	6 eggs	Mar.	7	early a.m.	2 eggs
,,	27	11 a.m.	1 ,,	,,	7	3 p.m.	1 ,,
,,	28	4 a.m.	6 ,,	,,	7	10 p.m.	1 ,,
,,	28	7 p.m.	1 ,,	,,	8	4.30 p.m.	1 ,,
,,	29	early a.m.	4 ,,	,,	12		1 ,,
,,	29	3 p.m.	4 ,,	,,	13		2 ,,
,,	29-Mar. 1	night	1 ,,	,,	14-15	24 hours from a.m.	7 ,,
Mar.	1-2	night	1 ,,	,,	15-16	,, ,, ,, p.m.	2 ,,
,,	4	early a.m.	1 ,,	,,	19		4 ,,
,,	4	3 p.m., average	4 ,,	,,	19	8-9 p.m.	1 ,,
,,	6	early a.m.	6 ,,	,,	19-20	night	1 ,,

Mar. 20	p.m.	1 eggs	April 8-9	night	2 eggs
,, 20-21	night	3 ,,	,, 9	3 p.m.	1 ,,
,, 21-22	24 hours from a.m.	1 ,,	,, 9-10	night	1 ,,
,, 22-23	,, ,, ,, p.m.	4 ,,	,, 11		1 ,,
,, 24-25	,, ,, ,, ,,	3 ,,	,, 11-12	night	1 ,,
,, 25-26	night	2 ,,	,, 13-15		1 ,,
,, 26	3 p.m.	2 ,,	,, 15-18		3 ,,
,, 26-27	night	2 ,,	,, 18-20	p.m. to p.m.	5 ,,
,, 27-28	24 hours from a.m.	2 ,,	,, 20	9 p.m.	1 ,,
,, 29-30	,, ,, ,, ,,	1 ,,	,, 23-25	p.m. to p.m.	5 ,,
April 2-3	night	1 ,,	,, 25-26		4 ,,
,, 4	2 p.m.	5 ,,	,, 26-27		2 ,,
,, 4	9.40 p.m.	2 ,,	,, 27-28		2 ,,
,, 5	3 a.m.	1 ,,	,, 29-30		1 ,,
,, 5-6	night	2 ,,	May 3-4		5 ,,
,, 6-7	,,	1 ,,	,, 4-12		7 ,,
,, 7-8	,,	4 ,,			
,, 8	3 p.m.	2 ,,		Total	139 eggs

Of these eggs all were fertile, excepting the five deposited April 18th-20th, four of the five—deposited between April 23rd and 25th, and all the others after that date excepting the last seven, nymphs from which were found on May 15th; these eggs, with the exceptions noted, shrivelled.

The female was allowed to engorge at 7 p.m., March 7th, responding to the stimulus after but a few seconds; an egg was deposited within the next few hours. And at 8.20 p.m., March 15th, the female engorged, responding at once; also at 8.40 p.m., March 20th, feeding to engorgement for nine and a half minutes; at 1.15 p.m., March 29th, 12 minutes (including three and a half minutes for insertion of the mouth setae), and again for seven and a half minutes at 9.15 p.m., April 4th, responding to the stimulus after a minute and a half, and approaching food after two minutes of exposure to it. Exposed to food at 9 a.m., April 12th, in full glare of an electric lamp, the female responded and went to food after forty seconds and fed for six and a half minutes, until glutted; its body was flat before feeding. On April 20th, 1908, it fed for fourteen minutes until glutted—during this period it was accidentally disturbed and left the food for a minute and a half. Immediately after feeding, on the way from the host, the bug suddenly turned around, backed quickly, then ran forward a short distance, at the same time expelling a streamlet of dilute inky excrementitious matter. This appears to be a characteristic action when expelling excrement. April 28th, at 10.10 p.m., the bug fed for ten minutes until glutted, going to the host after a minute of exposure. Since it had by this date become infertile, a male (No. 2 of generation II) was added at 9.35

p.m., April 30th. Mating did not occur within the next ten minutes, though the two recognised each other. The male was removed at 8 a.m., May 1st. Mating must have occurred since the last seven eggs deposited (May 4th-12th) hatched; but five eggs deposited May 3rd-4th did not.

In order to prevent actual starvation the female was fed for one and a half minutes at 8.30 p.m., May 16th (plus three minutes for insertion). She died, however, on May 19th, 1908.

(3) *Pair No. 3.*—Adult No. 3, a male, was partly fed at 7.30 p.m., February 18th, and adult No. 9 gorged itself at 8 p.m. the same day; the two were then confined together. They remained perfectly motionless some distance apart until covered. Fifteen minutes later they were discovered mating; the male was upon the dorso-lateral aspect of the female's back with the abdomen curved under that of the female. They separted after four minutes, probably because of the disturbance. The female had fed previously since maturity at 6 p.m., January 29th; the male as recorded under pair No. 1. Both gorged themselves at 6.45 p.m., February 23rd, the male not approaching the host until five minutes after the female; but at 6 p.m., February 29th, both went to the host at once and gorged, the female feeding for one and a half minutes longer than the male. Again at 7.30 p.m., March 7th, both sexes gorged themselves, the female going to the food first, followed by the male several minutes later. Both sexes engorged at 7.30 p.m., March 13th, the female as usual approaching the host first, running to it, but the male cautiously; the former fed for at least two minutes longer than the male. Oviposition commenced a few days following pairing, and as follows :—

Feb.	22-23	night	4 eggs	Mar.	7	day	2 eggs
,,	23	7.30 p.m.	3 ,,	,,	7	10 p.m.	1 ,,
,,	23-24	night	2 ,,	,,	8-10		3 ,,
,,	25	early a.m.	6 ,,	,,	11-12		1 ,,
,,	25-26		2 ,,	,,	13	p.m.	3 ,,
,,	27	early a.m.	3 ,,	,,	14-15		5 ,,
,,	27	7 p.m.	2 ,,	,,	15	day	3 ,,
,,	27-28		2 ,,	,,	16	10 p.m.	1 ,,
,,	28	noon	1 ,,	,,	16-17	p.m. to p.m.	2 ,,
,,	28	5-6 p.m.	3 ,,	,,	19		4 ,,
,,	29	early a.m.	1 ,,	,,	19	8-9 p.m.	2 ,,
,,	29	3 p.m.	2 ,,	,,	20	p.m.	1 ,,
,,	29	7 p.m.	1 ,,	,,	20-21	night	3 ,,
,,	29-Mar. 1		1 ,,	,,	21-22		3 ,,
Mar.	1-2		1 ,,	,,	22-23		2 ,,
,,	4	day	6 ,,	,,	24	p m.	2 ,,
,,	6	caily a.m.	5 ,,	,,	24-25		4 ,,
,,	7	,, ,,	1 ,,	,,	25-26	night	2 ,,

Mar.	26	day	2 eggs	April	11		3 eggs
,,	26-27	night	2 ,,	,,	15-16	night	3 ,,
,,	27-28	a.m. to a.m.	3 ,,	,,	16-18	p.m. to p.m	8 ,,
,,	28	late p.m.	1 ,,	,,	18-20	,, ,, ,,	3 ,,
April	3-4	p.m. to p.m.	6 ,,	,,	20	9 30 p.m.	1 ,,
,,	5	early a.m.	1 ,,	,,	23-25		6 ,,
,,	5-6	night	5 ,,	,,	25-26	p.m. to p.m.	3 ,,
,,	6-7	night	2 ,,	,,	26-27	,, ,, ,,	1 ,,
,,	7	day	2 ,,	,,	27-28	,, ,, ,,	1 ,,
,,	7-8	night	5 ,,	May	1-4		1 ,,
,,	8-9	night	1 ,,	,,	4-15		15 ,,
,,	9	day	3 ,,				
,,	9-10	night	1 ,,			Total	168 eggs

All of these hundred and sixty-nine eggs were fertile, excepting the one deposited between May 1st-4th, which shrivelled. At 8 p.m., March 20th, the pair were offered food and responded, the male last; they glutted themselves and then mated. At 1 a.m., March 29th, the female responded to the food stimulus and fed for nine and a half minutes, the male not responding. The latter was offered food several times at 8 p.m., March 30th, but did not go to it; the female, however, responded readily, but was prevented from feeding; her response was slower than usual. The male was active. On April 4th, at 8.45 p.m., the female responded to food after a minute and a half, the male a minute afterward, crawling upon the back of the female and apparently mating; the female fed this time for seven and a half minutes until glutted and then left, carrying the male with her; after a minute, the latter left the female and went to food, sucking for seven minutes; it had not fed while with the female. April 12th, at 9.30 p.m., the female responded and approached the food immediately, sucking for eighteen and a half minutes; but much of this time was occupied in attempts to piece the skin with the setae; at the same time the male responded to the stimulus with a slight movement, but did not approach. At 8.20 p.m., April 20th, both sexes responded at once, the female immediately approaching thereafter, and feeding for fourteen minutes until greatly distended; the male approached two minutes later and left two minutes earlier, also much distended. Upon leaving the food, the female crawled down near to the quiet male and then both rested for two minutes; then the female approached the male and rested her forebody across his, then deliberately turned around in her tracks. After several seconds the latter mated with her (dorso-lateral position); this act lasted for sixty-five seconds, and terminated with a few sudden spasmodic jerks of the male's body. The latter then crawled off the female. An egg was deposited at 9.30 p.m.

On April 29th at 9.55 p.m. the female fed for ten and a quarter minutes the male for nine and a quarter, the former responding at once, the latter following after one and a half minutes. After feeding, both immediately voided excrement, as is usual after a meal. The female died on May 10th, the male May 18th, 1908, both apparently from starvation.

This female hatched at noon, August 27th, 1907, and came to maturity on January 16th, 1908, at 11 p.m., after having been fed twenty times (but not to engorgement), and after moulting six times. It was fed for the first time after reaching maturity on January 29th, was mated on February 18th, and then deposited a hundred and sixty-nine eggs (February 22nd-May 15th) at the rate of two eggs per day.

The male hatched at the same time, and came to maturity on November 9th of the same year at 4 p.m., after having been supplied with eleven full meals. After maturity it was fed the first time on November 24th, and subsequently on December 19th; on December 22nd it was mated with adult No. 2 (see pair No. 1), with which it was confined until the death of that female on February 15th. It was then confined and mated with adult No. 9 of this pair as detailed above. It mated with two females.

(4) *Pair No. 4.*—On February 18th, 9 p.m. (1908), adults No. 10 and 8 were allowed to engorge, and were then confined together in a round wooden box. No. 8, the female, had fed previously at 6 p.m., January 29th; No. 10, the male, at noon, January 12th, and 6 p.m., January 29th. The first eggs were found at 7 a.m., February 23rd, the deposition being as follows :—

Feb.	22-23	night	3 eggs	Mar.	16	9.30 p.m.	1 eggs
,,	23	7 40 p.m.	1 ,,	,,	19		1 ,,
,,	23-24	night	2 ,,	,,	19	8-30 p.m.	1 ,,
,,	25	noon	1 ,,	,,	19-20	night	1 ,,
,,	25-26	night	4 ,,	,,	20	p.m.	2 ,,
,,	27	early a.m.	3 ,,	,,	20-21	night	3 ,,
,,	27-28		2 ,,	,,	21-22	a.m. to a.m.	3 ,,
,,	28	10 a.m.	1 ,,	,,	23-24	p.m. to p.m.	2 ,,
,,	28	6 p.m.	1 ,,	,,	24-25	,, ,, ,,	4 ,,
,,	29	7 a.m.	4 ,,	,,	25-26	night	1 ,,
,,	29	4 p.m.	1 ,,	,,	26	4 p.m.	3 ,,
Mar.	4	4 p.m.	5 ,,	,,	26-27	night	1 ,,
,,	6	early a.m.	3 ,,	,,	27-28	,,	2 ,,
,,	6	11 a.m.	1 ,,	April	3-4	p.m, to p.m.	5 ,,
,,	7	5 p.m.	4 ,,	,,	4	9.50 p.m.	1 ,,
,,	13	p.m.	4 ,,	,,	4	10.30 p.m.	1 ,,
,,	14-15	a.m. to a.m.	6 ,,	,,	4-5	night	1 ,,
,,	15	4 p.m.	1 ,,	,,	5	day	1 ,,
,,	15-16	p.m. to p.m.	1 ,,	,,	5-6	night	2 ,,

April	6	day	1 eggs	April	18-19	1 eggs
,,	7		1 ,,	,,	19-20	1 ,,
,,	7-8		3 ,,	,,	23-25	6 ,,
,,	8	day	1 ,,	,,	25-26	2 ,,
,,	8-9	night	3 ,,	,,	26-27	1 ,,
,,	9-10	night	1 ,,	,,	27-28	3 ,,
,,	11		3 ,,	May	4-11	9 ,,
,,	13-15	p.m. to p.m.	1 ,,			
,,	15-18		9 ,,			Total 130 eggs

All of these eggs were fertile. Both sexes were fed until gorged at 7 p.m., February 23rd, both going directly to the food. An egg was deposited thirty minutes later. Both were again allowed to engorge at 6.30 p.m., February 29th, both responding after a few seconds; at 7.30 p.m., they were found mating (end to end position). On March 7th, at 8 p.m., the response to the food stimulus was almost immediate, both running quickly to the host a second or two after exposure; also on March 15th, at 7.45 p.m., they were allowed to engorge, the male responding positively forty-five seconds slower than the female, and leaving the food a minute and a half earlier. At 8.20 p.m., March 20th, the female actually ran to the food immediately following exposure, the male following a quarter of a minute later, both engorging. The female approached the food just a few seconds before the male at 1.30 p.m., March 29th, and fed for seven and a half minutes until glutted; this time the male fed for five and a half minutes, and then left the food, ran "excitedly" to the female and mated (or at least attempted to) for five times in succession, each act lasting only one or two seconds, and done while the female still fed. The latter responded and after three quarters of a minute went to food at 9.25 p.m., April 4th, feeding for seven minutes; the male followed a minute after the female, and fed for four minutes. Both were glutted. On April 12th, at 8.40 p.m., in the presence of a bright light, the female went to food, at once feeding for twelve minutes, taking some time for insertion of the setae; the male this time ran rapidly to the host after about thirty seconds, and during the eleven and a half minutes ensuing tried "desperately" to feed, but was unable to insert the mouth-parts. It was flat from lack of food; the female was also flat before feeding.

Both sexes ran to the food immediately after exposure at 8.45 p.m., April 20th, the male leading. Both began to feed at once, the female for six and a half minutes, the male for ten; the latter was not repleted for the mouth-parts were inserted with difficulty. After feeding, as usual, both voided ecrement. This was done by rapidly backing, stopping, expelling the excrementitious matter, and as it came forth

running rapidly ahead; sometimes, at the commencement, a rapid turn about occurs, followed by the other movements. This is characteristic. At 10.5 p.m., April 29th, the female responded positively to the food stimulus at once, the male following after thirty seconds, pushing the female out of its place. Both then fed, the male for four and a half minutes, the female for eight minutes. Three minutes later mating occurred. The female died on May 11th, from necessary neglect, its body still fully coloured. After four attempts the male succeeded with the insertion at 8.30 p.m., May 19th, and fed to repletion. And again after two and a half minutes of insertion at 11.5 p.m., June 11th, feeding to repletion and for four minutes; before this meal it was still normal in colour and active. In the same condition, at 11.48 a.m., July 4th, the male fed for six minutes, including the time taken for insertion of the mouth-parts; at 12.55 a.m. it was placed with adult No. 1 (pair No. 2) in order to fertilize that female again; it was isolated again at 10 p.m. the same day. It died August 8th, 1908, fully coloured but thin, not having been fed since.

Thus, the female of this pair hatched at noon, August 27th, 1907, reached maturity at 6 p.m., January 17th, 1908, after having been fed twenty times (but never to repletion), was fed for the first time following maturity at 6 p.m., January 29th, and mated at 9 p.m., February 18th, after a second engorgement. Oviposition commenced four days later, and continued without break until death (May 11th), a hundred and thirty eggs being deposited at the rate of 1.5 per day.

The male had a history nearly similar to that of the female, hatching at the same time and similarly fed (*i.e.*, never to repletion), reaching maturity at 7 p.m., January 9th, 1908, after feeding sixteen times. It was mated on February 18th, and lived continually with the female until her death on May 11th; it was again mated on July 4th, but isolated after about twenty hours, dying shortly afterwards (August 8th, 1908).

2. *A Second Generation.* Direct descendants of the first generation, the following pairs originated from pair No. 1, which deposited eight eggs about 6 a.m., February 1st, 1908, these eggs hatching at about 4 p.m., February 10th, following (average time). All of the nymphs were fed to repletion at each meal, and were kept isolated. After reaching maturity they were paired off as narrated herewith.

(1) *Pair No. 1.* Adults No. 1 and 7, the former the female, were confined together in a small glass tube at 7 p.m., March 18th, 1908;

neither had fed since maturity. After several minutes they mated, the act lasting but two or three minutes (in bright light). Both went simultaneously to food at 7.30 p.m., March 19th, and they were then transferred to a coverglass box. Oviposition was as follows:

Mar. 25	6 p.m.	3 eggs	April 8	day	2 eggs
,, 25-26	night	1 ,,	,, 9	,,	1 ,,
,, 26	day	1 ,,	,, 11-12	night	3 ,,
,, 26-27	night	2 ,,	,, 12	day	2 ,,
,, 27-28	,,	1 ,,	,, 12 13	night	4 ,,
,, 29-30	,,	1 ,,	,, 13-15	p.m. to p.m	8 ,,
,, 30-31	,,	1 ,,	,, 18-19		1 ,,
,, 31	noon	2 ,,	,, 22-23		2 ,,
April 1		2 ,,	,, 23-25		11 ,,
,, 2	early a.m.	2 ,,	,, 25-26		2 ,,
,, 2	11 a.m.	1 ,,	,, 26-27		1 ,,
,, 2	midnight	1 ,,	,, 28-29		1 ,,
,, 4	9 p.m.	1 ,,	,, 29-30		1 ,,
,, 4	10.30 p.m.	2 ,,	,, 30-May 4		12 ,,
,, 5-6	night	3 ,,	May 4-11		3 ,,
,, 6	day	2 ,,			
,, 6-7		4 ,,		Total	86 eggs
,, 7	day	2 ,,			

At 8 p.m., March 26th, the female went to food immediately, and as usual the male followed after about twenty seconds, leaving much earlier. Both were again glutted at 7.50 p.m., April 1st, the male approaching the food as soon as the female and feeding for ten minutes; the female fed for nine and a half minutes. On April 7th, at 8.50 p.m., the female responded to the stimulus after a half minute, and fed for nine and a half minutes; her mate responded after a minute and a half, then went slowly to food, changed position because of disturbance, approached the female and leaped upon her back, clung to her and fed while in that position, leaving the food after four minutes and a half, fully gorged. Apparently, mating did not occur and the female continued feeding steadily after the male left. The female fed for nineteen minutes until glutted at 9.30 p.m., April 18th, approaching the food a minute before the male; the latter fed for seven minutes (including four minutes for insertion of the mouthparts) and then left, approaching again after several seconds, fed for four minutes (plus insertion), then leaving, but returning again after several minutes, but this last time retreating before reaching the host. At 8.30 p.m., April 26th, the male preceded the female to food by one and a half minutes and fed for eight minutes until glutted; the female fed for twelve minutes until glutted. The female died between May 8th and 14th, 1908, not having been fed again. The male was fed to repletion at 7.30 p.m., May 18th, and again at 11.20 p.m., June 15th. At 1.39 p.m., July 4th, it fed (until

satisfied) for eleven minutes, having difficulty with insertion of the mouth-parts. It was not fed subsequently and died of starvation on November 4th, 1908, still fully coloured.

The female of this pair came to maturity at 9 a.m., March 18th, and was mated ten hours later, obtaining its first meal on March 19th. It commenced to lay fertile eggs at 6 p.m., March 25th, continuing until May 11th or until its death, depositing them at the rate of about a little less than two per day. The female obtained seven full meals before reaching maturity. The male became adult at 2 p.m., March 17th, 1908, after six full meals.

(2) *Pair No. 2*. Adult No. 2 was added to the vial containing adult No. 3 (large) at 7 p.m., March 18th, 1908, neither having been fed since maturity; they apparently mated soon afterwards Both went to food simultaneously at 7.45 p.m., March 19th, after a few seconds of exposure to the host. They again glutted themselves at 8.30 p.m., March 26th, the larger (mistaken for a female) as usual approaching food first, a slight delay following exposure to the stimulus; about ten minutes later, the smaller followed, crawling upon the back of the larger male and feeding from that position. (*Note*. These actions were first taken for mating until it became known that both the adults were males). At 8.45 p.m., April 1st, food being offered the smaller responded after a minute, the larger after two minutes, feeding for three and a quarter, and three and three quarter minutes, respectively. Again at 9.20 p.m., April 7th, response to the stimulus occurred after one and a half minutes, and a half minute later the smaller male went to food, feeding until glutted (three minutes); three and a half minutes after the first response the larger male went to the host, meeting the smaller leaving; the latter pounced upon the larger's back and then off; after seven minutes the larger male stopped feeding and moved over about a quarter inch, commencing again and feeding for four and a half minutes longer (total of eleven and a half minutes). Once, during the meal, adult No. 2 approached the larger adult, mounted upon its back and then off again, but made no movements like those of mating.

On April 18th, at 10.15 p.m., the larger male approached the food a minute before the smaller; both fed to engorgement, the former for four and a half minutes, the other a minute less. But on April 26th, at 9.10 p.m., the smaller male responded and went to the host at once, becoming engorged after four minutes and a half. A minute afterward adult No. 2 went to the host and fed for six minutes. During the interval

and while feeding No. 2 often crawled upon the back of No. 3, acting as if to mate, even bending the top of the abdomen around beneath the other. At 9.35 p.m., April 30th, No. 2 was mated with female No. 4 of the first generation (which see). May 18th, 8 p.m., No. 2 preceded No. 3 to food by thirty-five seconds, and both fed to repletion; and again at 11.30 p.m., June 15th, 1908. July 4th, 1.12 a.m., No. 3 preceded No. 2 to the host by one minute, feeding for seventeen minutes, having great difficulty in puncturing the skin; it engorged, however. Adult No. 2 fed for seven minutes, and after finishing went over at once to No. 3, crawled upon its back, bending the tip of the abdomen under in the exact position of mating pairs; this occupied about a second of time, and was repeated twice hereafter in quick rushes to and from No. 3.

Both died about September 20th, 1908, without receiving further attention. Both adults hatched about 4 p.m., February 10th, 1908, and came to maturity at about 9 a.m., March 18th (No. 2), and 6 a.m., March 17th (No. 3) of the same year after receiving (No. 2) five and seven (No. 3) full meals, respectively. The further history is as above.

(3) *Pair No. 3.* Adults Nos. 5 and 6, the former the female, were placed together in a wooden cover-glass box at 7.30 p.m., March 22nd, 1908. They did not approach each other. Food being offered, the male went to it and gorged, after remaining quiet for several minutes. Upon leaving food it went at once to the female, but was evidently repulsed. The female then went to the host, glutted itself, left, and then actually ran to the male, which mated with her (dorso-lateral position); the act only occupied two or three seconds, but to all appearances was completed. Oviposition was as follows:—

Mar.	27	3 p.m.	1 eggs	April	9	day	3 eggs
,,	27-28	night	2 ,,	,,	11-12		6 ,,
,,	28	day	2 ,,	,,	12	afternoon	1 ,,
,,	29	3 to 8 a.m.	3 ,,	,,	13	10 a.m.	2 ,,
,,	29	day	1 ,,	,,	13	4-5 p.m.	3 ,,
,,	29-30	night	2 ,,	,,	13-15	p.m. to p.m.	4 ,,
,,	30-31	,,	4 ,,	,,	15	10 p.m.	1 ,,
April	1		3 ,,	,,	15-18	p.m. to p.m.	1 ,,
,,	2	early a.m.	2 ,,	,,	22-23	,, ,, ,,	2 ,,
,,	2	forenoon	1 ,,	,,	23-25	,, ,, ,,	7 ,,
,,	2	midnight	1 ,,	,,	25-26		3 ,,
,,	4	,,	1 ,,	,,	27-28		3 ,,
,,	4-5	night	2 ,,	,,	29-30		1 ,,
,,	6	day	5 ,,	,,	30-May 4		11 ,,
,,	6-7		3 ,,	May	4-15		4 ,,
,,	7	day	2 ,,				
,,	7-8	night	1 ,,			Total	89 eggs
,,	8-9	,,	1 ,,				

All these eggs were fertile. The pair glutted themselves from the host at 8.45 p.m., March 26th, both responding positively to the food stimulus at about the same time; at 7.50 p.m. they had been observed to mate (to appearances), the act lasting but several seconds, and occurring under a bright light. At 8.10 p.m., April 1st, the female after responding at once to the stimulus, fed for seven minutes and to repletion. Just as it turned to leave the host the male ran forward and upon meeting the other pounced upon its back and mated. After half a minute the two parted, and some seconds afterward the male went to the host and fed for three and a half minutes to repletion. On April 7th, at 10 p.m., the female responded to the food stimulus a half minute after exposure, the male immediately following it to the host, crawling on to the female's back; both commenced to feed, but the male left before insertion of the setae and took another feeding position. The female fed for seven minutes, the male a half minute less.

April 18th, at 10 p.m., the female went to food a minute before the other, and fed for seven minutes to repletion. The male fed for four and a half minutes. At 8.50 p.m., April 26th, the female fed for twelve and a half minutes, becoming enormously swollen; the male held back, but eight minutes after the female commenced to feed it ran suddenly forward and jumped upon the female's back, feeding from that vantage for four minutes and a half. Both left at the same time, and immediately thereafter voided excrement.

The female died on May 15th, apparently from starvation. The male engorged at 8 p.m., May 18th, and again at 11.50 a.m., June 15th. At 2.2 a.m., July 4th, the male again accepted food and fed for nine and three quarter minutes. It died on September 24th, 1908, without other meals. The female of this pair hatched at about 4 p.m., February 10th, 1908, and came to maturity at 6 a.m., March 22nd, after seven full meals; the male hatching at the same time matured at 7 a.m., March 19th, after the same number of meals.

(3) *A Third Generation.* A third generation was directly descended from the second generation, pair No. 3. The eggs hatched at the average time of 2 a.m., April 20th, 1908 (see part II). The following matings were made, but not very carefully watched.

(1) *Pair No. 1.*—Adults No. 1 and 2, the former the female. Confined together at 10 p.m., July 19th, 1908. But few eggs resulted, as follows :—

July 26	6 a.m.	2 eggs	Aug. 10	4 a.m.		10 eggs
,, 26	7 p.m.	3 ,,				
,, 27	6 a.m.	5 ,,			Total	*20 eggs

All of these eggs were fertile. On July 31st, at 9 p.m., the pair were glutted and again at 4.30 p.m., August 10th. The female died September 1st; the male, October 2nd, 1908. Neither were fed until after they had been mated.

(2) *Pair No. 2.*—Adults No. 4 and 6, both females, hence no eggs. Fed on June 19th, 1.50 a.m., after mated, July 31st, 9 p.m. and 7.30 p.m., October 9th, 1908. They died about January 15th, 1909.

(3) *Pair No. 3.*—Adults No. 3 and 5, both females. Confined at 10 p.m., July 19th, 1908, died on September 18th, 1908, after receiving but one meal (at 9 p.m., July 31st).

Supplementary Notes.

An adult male captured in a bed in a hotel at Normal, Illinois (U.S.A.), 10 p.m., March 18th, 1910, coloured but not recently fed, was kept in a tin box and fed at 1.10 p.m., March 20th; responded positively to the stimulus after two minutes of exposure; after three minutes the setae had been inserted and engorgement resulted after five minutes. On March 26th, a larger adult male was captured at 2.20 a.m., on my leg immediately after getting out of a bed in a hotel in Chicago; at 2 p.m., March 30th, it was placed in with the first one; this second male when captured was coloured and partly fed. First, however, it was fed for seven minutes and a half (plus a minute and a half more for insertion). When the meal was completed, the first male immediately climbed upon its back and assumed the position of mating, riding thus for ten minutes; no actual mating, of course, but these actions could be easily mistaken for such. During the time that the Chicago specimen fed, the Normal male, unfed since March 20th, and hiding under the loose paper in the box, responded several times to the stimulus, but gave a negative reaction upon reaching full daylight. It responded positively after seven minutes' exposure at 8 p.m., March 30th (in shadow), feeding to repletion for four and a half minutes (plus three minutes more for insertion). Upon engorgement it backed off, turned round, stopped, backed again, and then while voiding a drop of excrement, walked forward. The other male responded sooner, but did not feed. Both died, fully coloured, April 20th, 1910, without other meals.

Tropisms.

Bedbugs react to certain physical stimuli characteristically. The reactions to light and food are those most strongly marked, while the individuals also react to contact. In regard to light, the nocturnal

habit of the species is well known. Nevertheless, although this reaction normally is markedly negative, its strength is weakened by the stimulus of hunger. Thus, while the species is normally nocturnal and feeds nearly always at night in the presence of a constant host, yet when the presence of the latter is unconstant and hunger supervenes the latter becomes dominant, and the insect will overcome its negative reaction. Hence, bedbugs will visit a host in daylight or in bright, artificial lights (electricity, coal gas) when hungry. However, the food stimulus may cause them to enter a light field gradually, indicating that they soon become accustomed to light; as soon as the food stimulus is neutralized by engorgement, however, the negativeness to light becomes dominant again, and the insect runs off to hide itself. The greatest dominance of the food stimulus over negative phototropism appears to occur when a hungry individual has actually commenced to suck blood

The reaction to food is characteristic and marked; thus, when confined in a small pillbox, as noticed already, and the latter is opened and its edge tilted against the naked arm, the insect first makes no movement. It shows no immediate indicative response to the stimulus. After a varying interval, maybe of not more than several seconds, it makes a (or several) short, sudden, jerky movements, immediately relapsing into immobility; this is what may be taken to be the actual response to the stimulus, the unconscious recognition of the presence of the food. After this, advance to the food is made, directly after some seconds or else indirectly, a number of indirect movements in the general direction of the food being made. Food is then taken to engorgement, excretion follows, and the bug then hides itself.

Reaction to contact is evidenced by the fact that these insects nearly always insert themselves into crevices, so that both sides of the body are in contact with an object. When hiding in holes, such as vacant screw-holes in wooden bedsteads, a number are usually piled one upon the other. Their flat bodies as well as their habits tend to show that the reaction is a real one. Thus they are gregarious (but not cannibalistic, at least in confinement), and as noticed, the pairs, or two males, seemed to like contact, frequently crawling over each other.

These three reactions seem to be the dominant ones in the life of the Cimex.

Food.

Cimex lectularius has never been known in nature to feed upon any other host than man. Experimentally, myself and others have shown that it will readily feed upon mice (Girault and Strauss, 1905) young and

old; later, I have seen hungry individuals feed readily upon the blood of the English Sparrow, the North American Mole, and the Guinea Pig. Many individuals subsisted for several months on the blood of the latter, and oviposition occurred. The same individuals will feed upon two different hosts (in confinement), as the guinea pig and man, or the sparrow and mice, after having lived upon man. Bedbugs have been observed feeding at as low a temperature as 56° Fahrenheit.

Miscellaneous and Concluding Notes.

The following observation was made upon an isolated individual now in the ultimate larval stage, but captured five months previously and fed irregularly. It was inverted over the under surface of the forearm at 7.55½ a.m., March 31st, 1906, and immediately attempted to feed, the labium bending in three places, the setae straight; it had not fed previously since the fifteenth of November preceding. The first blood entered the body not until after four minutes, and the abdomen was much distended two minutes later; feeding ceased after six and a half more minutes. While feeding the pulsations in the head, near the base of the nostrum were at the rate of three per second; the insect was immensely swollen after this meal. On November 15th, preceding, it fed for eight minutes; on May 9th, 1906, it engorged from the cold body of a dying mole, and twelve days later fed on human blood for four minutes and a half; and on June 2nd following, for seven and a half minutes, both times to engorgement. Reaching maturity after moults on September 28th, 1905, and April 13th, 1908, a few infertile eggs were deposited. This individual was captured from a human bed, fed once from the blood of a common house mouse, twice on human blood, once on that of the mole, and then twice more on human blood.

Upon hatching the bedbug is perfectly white, becoming after several hours a light straw yellow. After the first full meal all of the body is coloured red excepting the extreme tip of abdomen, the head, thorax and legs.

I have captured bedbugs in large numbers from the common types of iron bedsteads, so that it is a fallacy to think that they are adverse to hiding in them. These captures were made from single beds in hotels and boarding houses, and also from beds ranged side by side in numbers in the large rooms of cheap lodging-houses in cities; in the former cases the insects were hiding in the walls of the rooms, but in the latter in the beds themselves.

When feeding bedbugs have an "alert" attitude, and while punc-

turing the skin a slow, back and forward motion is made; after actual feeding commences, slow, gradual movements do not greatly disturb them as the movement is followed up. The movements of a sleeping host would not greatly disturb them, at least not so much as to deter them from obtaining satisfaction; they readily return to the host if disturbed sufficiently to cause temporary retreat.

A fertile egg shrivels as the embryo develops, and several longitudinal sunken areas appear about the time the body of the embryo becomes visible. Two young and pale bugs of the first stage captured while hiding in the crease at the edge of a mattress in a berth on an excursion steamer at about eleven o'clock, August 7th, 1907, were at once place together in an ordinary pillbox and left unfed. One died on the fourth of September following, the second seven days later. This observation was overlooked, and should have been included in part II.

LITERATURE REFERRED TO.

1905. Girault, A. A. and J. F. Strauss. Psyche, Boston, pp. 117-123.

REFERENCES TO PREVIOUS PAPERS ON THE BEDBUG.

In order to bring together all of my published data on this insect, I append the following list of articles:—

1905. Psyche, Boston, pp. 61-74.
1906. Ibidem, pp. 42-58.
1906. Journ. American Medical Assoc., Chicago, xlvii, pp. 85-87.
1907. Science, New York, new series, vol. xxv, p. 1,004.
1907. Zoologische Annalen, Wurzburg, pp. 143-201.
1908. Psyche, Boston, pp. 85-87.
1908. Zoologische Annalen, Wurzburg.

CORRECTIONS.

The following errors occurred in printing part II of this series:—

Page 165, line 7, for maxim *read* maximum; line 17 for 10--liniata *read* 10=lineata.

Page 168, first footnote, line 1, for plant *read* planting.

Page 172, line 25, for where *read* when.

Pages 178-181, Tables III and IV, line 1, sex names should be in the singular.

ON SOME COCCID PESTS FROM THE SEYCHELLES.

By E. ERNEST GREEN, F.Z.S., F.E.S.

A SMALL collection of insect pests, received from Mr. R. Dupont, Superintendent of Botanic Gardens, Seychelles, contains the following species of Coccidae :—

1. *Aspidiotus ficus*, Ashm.; on leaves of *Zamia* sp.

Zamia is an ornamental Cycad largely cultivated in tropical gardens. It is subject to numerous insect pests, of various orders, and the present species adds one more to the recorded number.

2. *Aspidiotus bromeliae*, Newst.; on leaves of Pineapple.

The discovery of this species, in the Seychelles, is of peculiar interest, as, hitherto, it has been recognized only from examples found on pineapples purchased in the English fruit markets, and said to have been imported from the Canary Islands. (Vide "A Monograph of the British Coccidae," Newstead, Vol. i., p. 87). The question arises, Is the species indigenous in the Seychelles? Or is it, there also an introduction? Judging from the extensive infestation of the single leaf submitted to me, *A. bromeliae* promises to be a somewhat serious pest to the cultivator of pineapples in the tropics. Its introduction to other countries should be guarded against by careful quarantine regulations. Serious pests are usually introductions, and, *vice versa*, imported insects are more likely to develop into serious pests. In view of the possible importance of this particular pest, it is desirable to ascertain the real headquarters of the species. It has not been recorded from the West Indies or the American continents. Mr. Newstead's evidence points to the Canary Islands. If it should be found to occur on indigenous Bromeliads, in those islands, the presumption would be stronger.

3. *Lecanium hesperidum*, auct., and 4. *Lecanium tessellatum*, Sign.; on leaves of the "Water Hyacinth."

The Water Hyacinth, though of considerable beauty, has proved itself to be an unmitigated plague in many countries where, by its excessive and rapid growth, it has blocked the waterways. These

insects, therefore, may be considered beneficial in their relation to this particular plant.

5. *Lecanium hemisphaericum*, Targ.; on leaves of *Justicia gendarussa*.

Many of the Justicias are ornamental flowering shrubs. They appear to be particularly liable to Coccid infestation. In Ceylon, most of the cultivated species of *Justicia* fall victims to *Orthezia insignis*. *Lecanium hemisphaericum* is a cosmopolitan pest, and no plants (except, perhaps, those of the orders *Coniferae* and *Gramineae*) appear to be immune to its attacks.

Bearsted, Kent, 20 Oct., 1913.

REVIEWS.

THE FUNGI WHICH CAUSE PLANT DISEASES. By F. L. Stevens. Pp. ix + 754, 449 figs. New York: The Macmillan Company, 1913. Price 17s. net.

Mycologists and students of mycology have long required a concise and handy text-book of the more important cryptogamic parasites affecting economic plants, with sufficient keys and descriptions to enable their identification, and Professor Stevens' latest work goes far to provide this.

With the works of Saccardo, Engler and Prantl and others to draw upon, we should have liked to have seen better Keys, for most of them are too brief for the student, indeed brevity might be said to be the chief fault in this work, in spite of its seven hundred printed pages. Many genera embracing a large number of species are dismissed with a description of two or three lines. Much space might have been saved by a different arrangement of the various bibliographies (some of the titles and references are very bewildering) which occupy upwards of forty pages. Finally, in a work of this kind, it is hardly necessary to reproduce figures of the fruit-bodies of the larger Basidiomycetes.

All the above are, of course, matters of individual opinion, and our questioning of their value does not in any sense mean that we fail in our appreciation of a very excellent work which must prove of great value to all students.

OUR COMMON SEA-BIRDS. By Percy R. Lowe. Pp. xvi + 310 and 239 figs. London: "Country Life" Ltd. [1914]. Price 15s. net.

Of the numerous illustrated books on birds, and there is no dearth of them, few have anything to recommend them beyond the illustrations. The details as to life-history, habits, migration, etc., are most meagre and not always correct. Mr. Lowe's beautifully illustrated work is of a very different character. The illustrations throughout are charming, but there is in addition a wealth of information on the habits, migration, nesting sites, methods of feeding the young, food, distribution, etc., all described in simple and clear English. Further, we have special chapters by Mr. W. P. Pycraft on the natural history of the Cormorant and on the Guillemot's eggs, by Mr. Bentley Beetham on the

flight of birds, by Mr. W. R. Ogilvie-Grant on the changes of plumage in the Cormorant and another on the Little Auk, by Mr. A. J. R. Roberts on the home of the Skuas, and one by Dr. Francis Heatherley on the Puffin at home, all of which add to the interest of the work.

It is some time since we have been so interested in a "bird-book," and look forward with much interest to the appearance of the second volume. In this we hope the author will give a detailed bibliography of the numerous works quoted from.

No one interested in the natural history of birds should fail to secure a copy of this enchanting work, which reflects the greatest credit on author and publishers, and the numerous naturalist-photographers who have assisted.

THE BRITISH RUST FUNGI (Uredinales) their Biology and Classification. By W. B. Grove. Pp. xii + 412, 290 figs. Cambridge: The University Press. Price 14s. net.

During the past twenty years very rapid strides have been made in our knowledge of the physiology and morphology of the different groups of fungi. Since Plowright wrote his justly eminent Monograph on the Uredineae, the works of the brothers Sydow, Ed. Fischer, and McAlpine have been issued, and a host of other workers have contributed to the advancement of our knowledge of the Uredinales or Rust Fungi.

In the work before us much of this knowledge has been summarised, together with many original observations and a distinctly refreshing method of treatment.

Mr. Grove divides his book into two parts, the first treating of the life-histories and reproduction, with chapters on immunity and classification and phylogeny; whilst the second is devoted to the purely systematic part. Here closely allied forms have been grouped, in a few cases, under a common name, and we welcome this stand against the excessive multiplication of species. The inclusion of the figures in the text is also very helpful.

This volume gives evidence of really careful and patient work, and must for some time to come be regarded as the leading text-book on the subject.

THE DISEASES OF TROPICAL PLANTS. By M. T. Cook. Pp. xi + 317, 85 figs. London: Macmillan & Co., Ltd., 1913. Price 8s. 6d. net.

This is a work intended primarily for the planter, and Dr. Cook is to be congratulated on its production. As most students of the pathology of tropical plants are aware, the literature on the subject is

scattered, frequently very indefinite in character and generally inaccessible.

The author has fully grasped the kind of work that will prove of value to the planter, and the descriptions and information given under the different plants is always concise, clear, and practical. This is seen again in the chapter on prevention and control.

To the student the work forms a most useful introduction to the diseases of tropical plants, whilst a very full bibliography to the general literature on the subject and the special monographs and writings on the diseases of particular plants will prove most helpful.

We look forward to further and much enlarged editions of this excellent work.

THE DISEASES OF ANIMALS. By N. S. Mayo. Eighth edition, pp. xvi +459, 59 figs. New York: The Macmillan Company. 1913. Price 6s. 6d. net.

The fact that Professor Mayo's book has now reached its eighth edition may be taken as an indication that such a work was needed, and that this particular one has met the demand.

The present edition differs little from previous ones. The different diseases are clearly and concisely described, and illustrated by carefully selected figures. There is a distinctly "common-sense" flavour about many of the methods of treatment, which will recommend the work to the farmer and all who have the care of domestic animals. Special attention has been given to the use of domestic and simple remedies, whilst complicated medicinal treatment, frequently dangerous in unskilled hands, has been purposely omitted.

Special emphasis is laid upon prevention, sanitation and careful handling, and generally upon a more rational treatment of animal diseases.

MILDEWS, RUSTS AND SMUTS. By George Massee, assisted by Ivy Massee. Pp. iii + 229. London: Dulau & Co., Ltd. 1913. Price 7s. 6d. net.

Mr. Massee's useful and compact synopsis of the families Peronosporaceae, Erysiphaceae, Uredinaceae and Ustilaginaceae will prove most useful to those mycologists interested in these families, but the value of the work, would, we think, have been considerably increased had the 64 figures, given on the four plates at the end of the volume, been introduced in the text

Apart from excellent descriptions throughout, there is a very full index of genera and species and one of host plants. The book cannot fail but prove a most useful handbook.

THE LIFE-STORY OF INSECTS. By Geo. H. Carpenter. Pp. iv + 134 and 23 figs. Cambridge: The University Press. 1913. Price 1s. net.

Professor Carpenter set himself no easy task when he decided to portray the story of the transformations of insects in a little over a hundred pages of these delightful Cambridge Manuals. He has succeeded, however, in presenting a most interesting account of the adaptations and modifications of larvae and pupae and of the general metamorphoses of insect life, in spite of the limitations of space.